ELECTRIC WIRING

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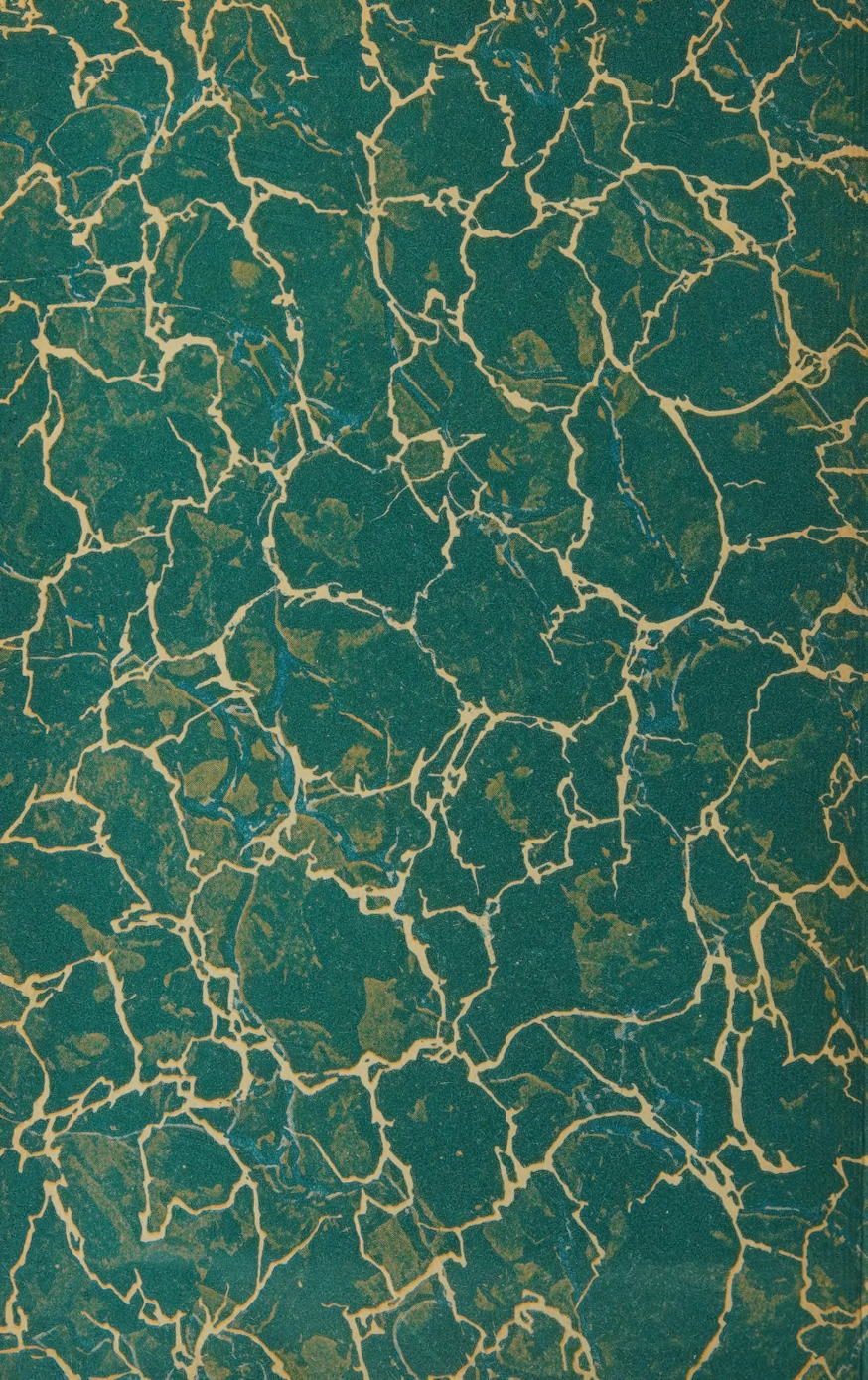

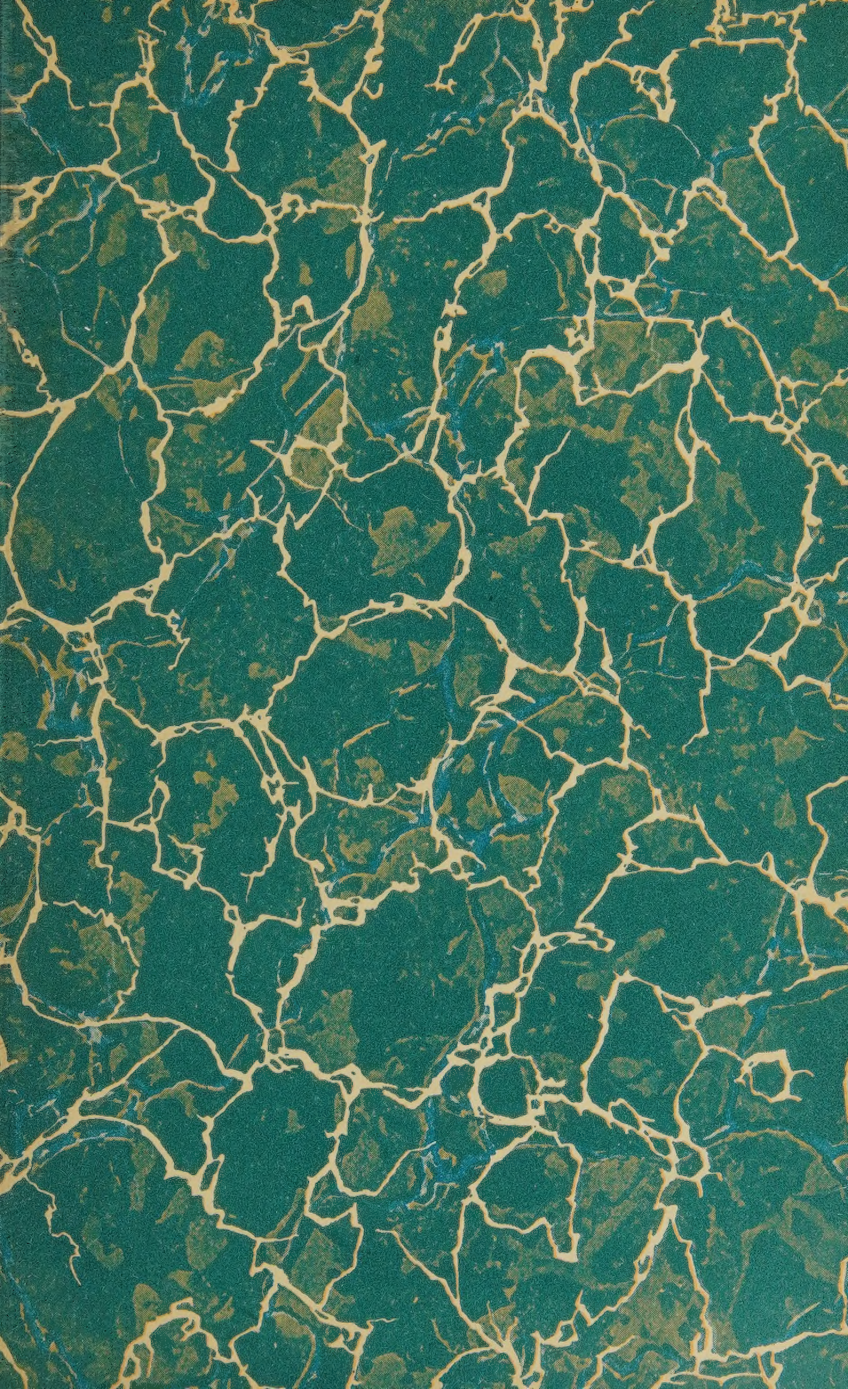

Electric Wiring

By
I.C.S. STAFF

ELECTRIC WIRING, Parts 1–2

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INTERNATIONAL TEXTBOOK COMPANY
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International Textbook Press
Scranton, Pa.

80760

CONTENTS

NOTE.—This book is made up of separate parts, or sections, as indicated by their titles, and the page numbers of each usually begin with 1. In this list of contents the titles of the parts are given in the order in which they appear in the book, and under each title is a full synopsis of the subjects treated.

ELECTRIC WIRING, PART 1

	Pages
Elementary Electrical and Magnetic Theory	1– 2
Electricity; Electromotive force; Conductors and non-conductors; Electric circuit.	
Primary Cell	3– 4
Kinds of Current	5
Electrical Units	5– 7
Ampere; Ohm; Volt; Ohm's Law; Watt.	
Simple Electric Circuits	8– 9
Series connections; Parallel, or multiple, connections; Switch; Grounded circuit; Short circuit.	
Voltage Drop and Energy Loss	10
Primary Magnetic Definitions	11–12
Generators and Motors	13–14
Elementary Alternating-Current Definitions	15
Polyphase Alternating Currents	15
Alternating-Current Machinery	16–17
Induction motor; Transformers; Rectifier.	
Miscellaneous Definitions	18–20
Load; Storage cell; Motor-generator; Switchboard; Bus-bar; Feeder; Main; Relay; Magneto.	
National Electrical Code	21–22
Wiring for Light and Power	23–60
Distribution Systems	23–30
Fundamental systems; Commercial systems; Feeder and main systems.	
Wires and Cables	30–36
Wire Units and Gauges	32
Insulation	33

ELECTRIC WIRING, PART 1—(*Continued*)

	Pages
Sizes of Wires	34
Flexible cords; Carrying capacity of insulated wires.	
Cut-Outs and Switches	37–48
Fuses; Circuit breakers; Knife switches; Snap switches; Special switches and control circuits.	
Exposed Wiring	49–57
Knob insulators; Cleats; Exposed wiring insulation; Insulation requirements.	
Concealed Knob-and-Tube Work	54–57
Molding Work	58–60

ELECTRIC WIRING, PART 2

Light and Power Wiring	1–72
Conduit Work	1–17
Rigid conduit; Conduit fittings; Installing vertical and horizontal runs of concealed conduits; Exposed pipe-conduit work; Flexible-conduit work; Armored cable.	
Miscellaneous Accessories and Fittings	18–25
Lamp sockets and receptacles; Panel boards and cabinets; Fixture supports.	
Transformers, Service Entrances, Switch Boards, and Meters	26–31
Heat, Power, and Special Lighting	31–36
Electric heating; Electric motors; Electric signs and display wiring.	
Low-Voltage Wiring	37–72
Sources of low-voltage energy; Storage batteries; Low-voltage alternating-current devices.	
General Requirements for Low-Voltage Wiring	40–41
Signal Appliances and Simple Bell Systems	42
Call-Bell Systems	43–45
Burglar and Fire-Alarm Systems	46
Miscellaneous Low-Voltage Systems	47–48
Telephone Wiring	49–60
Hints on Wiring	61–69
Jointing; Concealed work in completed building; Insulation of concealed-conduit work.	

ELECTRIC WIRING, PART 2—(*Continued*)

	Pages
Tests	72
Location and Calculation of Feeders and Mains	73–85
Location of feeders and mains; Direct-current calculations; Alternating-current calculations.	
Estimates	86–87

ELECTRIC WIRING
(PART 1)

Serial 1839A Edition 1

ELEMENTARY ELECTRICAL AND MAGNETIC THEORY

DEFINITIONS AND DESCRIPTIONS

INTRODUCTION

1. Electricity.—Electricity is a name given to the cause of certain phenomena or manifestations, although the exact nature of this cause is not known. Much is known, however, about the laws governing electricity. For example, certain substances can be made to attract or repel other substances, chemicals can be decomposed, heat can be developed, and so on, by the use of electricity.

2. Static Electricity.—Electricity at rest is called static electricity. This is the kind produced by rubbing a hard-rubber comb or a piece of glass with a woolen cloth. The comb or the glass, when so rubbed, is electrified, or charged. In other words, the comb bears a static charge of electricity.

3. Dynamic, or Current, Electricity.—Electricity in motion is called dynamic, or current, electricity. Because the action of electricity in motion resembles in many respects the action of fluids in motion, it is common to speak of the *flow of electricity*. This flow is called an *electric current*. A momentary flow is generally called a *discharge*.

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4. Electromotive Force.—Force is necessary, however, to cause a flow, or current, of electricity. This force is called an *electromotive force* (e.m.f.).

5. Electric Potential.—Electric potential is a term used to signify the state or condition of a body whereby electricity tends to flow into it or out of it. If its electric potential is lower than that of another body with which it is electrically connected, electricity will flow into it. In short, electricity tends to flow from bodies of higher potential to bodies of lower potential.

6. Conductors and Non-Conductors.—Electricity, like water, if permitted to flow unconfined, selects the easiest path. The rate of flow of electricity, however, depends primarily on the nature of the substances through which it flows. Those substances through which electricity flows readily are called *conductors,* or *conducting substances,* and those offering great opposition to the flow are called *non-conductors,* or *insulators.* In order that the energy may be utilized efficiently, the current must be confined within a definite path, like a wire. To prevent the current from leaving the wire, supports of some non-conducting substances, like glass or porcelain, are used to hold the wire and prevent it from coming in contact with surrounding materials. A wire is a conductor and each support is an insulator. As a further precaution, the wire is usually covered throughout its length with rubber or some other pliable non-conducting substances called *insulation.*

7. Electric Circuit.—An electric circuit is a conducting path through which electricity will flow when the path is complete between points of different potentials. A complete, or unbroken, path between such points is a closed circuit; an incomplete, or broken path, is an open circuit.

8. The direction of current in an electric circuit is assumed to be from the condition called *high,* or *positive, potential* to the condition called *low,* or *negative, potential.* The signs + and −, respectively, are used to indicate these two conditions. Thus, electricity is said to flow from + to −.

9. Electric resistance, generally defined, is opposition to the flow of electricity. No known substance is wholly without resistance, which depends on the nature of the substance. The resistance of a conductor depends on its material and its dimensions. The resistance of a long wire is greater than that of a short wire of the same diameter and material. The resistance of a wire of large diameter is less than that of a small wire of the same length and material.

10. The electric conductance of a wire is a measure of its ability to conduct electricity. Good conducting materials, named in order, with the best conductor first, are silver, copper, gold, aluminum, zinc, brass, phosphor-bronze, platinum, tin, nickel, lead, German silver, steel, iron, mercury, carbon, and water. Copper, being plentiful and comparatively cheap, is most generally used, and aluminum is also employed for long transmission lines.

11. A resistor is a device purposely designed to oppose the flow of electricity. Resistors are a part of many heating devices and of certain types of electrical measuring instruments.

Insulating materials in general use are glass, porcelain, rubber, mica, ebonite, dry paraffined wood, prepared paper, and other fibrous materials, asbestos, pure asphalt, air, oils, and various substances of patented or secret composition.

PRIMARY CELL

12. Generation of Electromotive Force.—The methods most commonly used in generating electromotive force are: (*a*) by chemical action; (*b*) by electromagnetic induction; (*c*) by heat action. The first method is used for generating small electromotive forces and currents for electric-bell systems and alarm systems.

13. Primary, or Galvanic, Cell.—The device for establishing an electromotive force by chemical action is called a primary cell, or galvanic cell. In Fig. 1 (*a*) is shown the simplest form of primary cell, consisting of a copper plate *C* and a zinc plate *Z*

immersed in dilute sulphuric acid contained in a glass jar *A*. The acid attacks the zinc more vigorously than it does the copper, with the result that the zinc plate is raised to a higher potential than is the copper plate, thus tending to cause electricity to flow from the zinc to the copper through the liquid. If the two plates are electrically connected outside the cell, as would be the case if the two conductors shown attached to the plates were joined together, electricity will flow from zinc to copper through the liquid, and from copper to zinc outside the

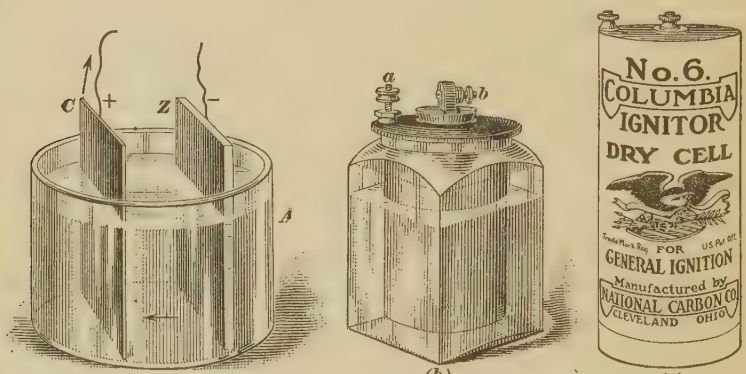


FIG. 1

liquid. In (*b*) is shown a type of liquid cell in common use, while (*c*) shows a dry cell embodying the same principle.

14. Primary Battery.—A primary battery is a group of primary cells so connected electrically that either their currents or their electromotive forces are added. To provide a convenient means of connecting cells, either together or to external conductors, thumbscrews, binding clips, or similar devices are attached to the plates as shown at *a* and *b*, Fig. 1 (*b*). Such devices are called the cell terminals. The word *terminal* has a similar meaning when used in reference to other kinds of electrical appliances. In general, a terminal is a point at which the external circuit is connected to the internal circuit of any electrical apparatus.

KINDS OF CURRENT

15. The current generated by a primary cell has an unchanging direction with respect to its source. Such a current is called a *direct current* (D. C.). A circuit carrying a direct current is called a direct-current circuit.

An *alternating current* (A. C.) is one that reverses its direction regularly, and its path is an alternating-current circuit. Until the topic of alternating current is taken up, the following discussion applies to direct currents only.

ELECTRICAL UNITS

16. Electricity is measured by its effects or by the work it does. In order to measure these effects, it is necessary to establish units by which these may be computed. The units in common use are the ampere, ohm, volt, watt, kilowatt, kilowatt-hour, and horsepower.

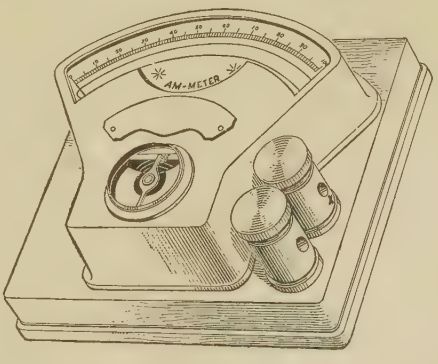


Fig. 2

17. The **ampere** is the practical unit rate of flow of electricity, or unit current. The ampere as a unit of flow of electricity corresponds to the gallon per second as a unit of flow of water. The practical unit of electrical quantity is the ampere-hour, which is equal to the flow of one ampere of electricity for one hour. The term *amperage* is sometimes used to denote the strength of an electrical current measured in amperes.

18. In practical work, electric current is measured by means of an instrument called an *ammeter,* a portable type of which is shown in Fig. 2. The ends of the conductors are inserted in the terminals shown at the right, and the effect of the current in the circuit causes a pointer to deflect over the scale to a figure

indicating the rate of flow directly in amperes. In this illustration the pointer is at zero.

19. The **international ohm** is the practical unit of electric resistance and is determined by the resistance of a column of mercury of specific dimensions or by a standard coil of wire. The word *ohm,* as generally used, refers to the international ohm.

20. It is customary to state that a wire of a given material having specified dimensions and at a given temperature has a resistance of a certain number of ohms. In wiring work, the value of 10.8 ohms, approximately, is often used as the resistance in ohms per foot of a uniform circular wire 1 mil (1/1,000 inch) in diameter.

21. The **volt** is the practical unit of electromotive force, and is the electromotive force that will cause electricity to flow at the rate of 1 ampere through a circuit having a resistance of 1 ohm. Derived from the unit is the word *voltage,* which is the name generally used to express electromotive force. It is easier to say "the voltage is 110" than to say "the electromotive force is 110 volts."

22. The definition of a volt shows that a certain relation exists among values of voltage, current, and resistance in an electric circuit. This relation, named after its discoverer, Ohm, is called Ohm's law, and is as follows.

Ohm's Law.—*The current in an electric circuit varies directly as the electromotive force is impressed on the circuit, and inversely as the resistance of the circuit.*

Expressing the law as a formula, using the three fundamental units,

$$\text{amperes} = \text{volts} \div \text{ohms}$$

$$\text{volts} = \text{amperes} \times \text{ohms}$$

and

$$\text{ohms} = \text{volts} \div \text{amperes}$$

Thus, any one of the three factors can be found if the other two are known.

23. In practical work, voltage is generally measured by means of an instrument called a *voltmeter,* a device having much

the same external appearance as an ammeter, but designed to indicate electromotive force directly in volts. Voltmeters are made in many styles, or types, and for many ranges of voltages.

24. Work is done on a circuit when a quantity of electricity, which may be expressed in ampere-hours, is forced by the voltage to pass through the circuit. Work is required to send the electricity through the circuit, and this work can be recovered by utilizing the electric current. Work takes into consideration voltage, current, and time. A water analogy is that of the work done on a water-pipe system when the pressure applied to the water forces a quantity of water through the pipe.

25. **Power** is the rate of doing work, or power = work ÷ time. The watt is the practical unit of electric power, and 1 watt is expended when a direct current of 1 ampere is forced through a resistance of 1 ohm. The power, expressed in watts, also equals the amperes of current multiplied by the volts. In the rating and measurement of power of large electrical apparatus and circuits, the *kilowatt* (abbreviated kw.) equal to 1,000 watts, is the unit generally used. Kilowatts = watts ÷ 1,000.

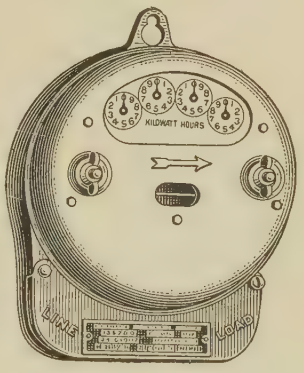


FIG. 3

26. As work = power × time, a unit of work can be derived by taking the product of a unit of power and a unit of time. Two practical units of electrical work, the watt-hour and the kilowatt-hour (abbreviated kw.-hr.), are thus derived. Electrical energy is nearly always bought and sold in kilowatt-hours.

27. The name *watt-hour meter* is applied to an instrument arranged to measure electrical work whether the amount is registered in watt-hours or in kilowatt-hours. The watt-hour meter is the instrument that is generally referred to in common electrical parlance as a *meter*. Several forms of watt-hour meters are in use, one of which is shown in Fig. 3.

SIMPLE ELECTRIC CIRCUITS

28. Series Connections.—Electric conductors can be connected in several ways. When the connections are such as to form only one path for the flow of electricity, the connection, or grouping, is a series connection and the apparatus or conductors are *in series*. For example, Fig. 4 represents a closed circuit consisting of a simple primary cell B and four conductors a, b, c, and d connected in series; that is, electricity can flow from the positive terminal of the cell to the negative terminal through only one path. An opening in any part of this series circuit would prevent all flow in it. In the illustration is shown the conventional way of representing a cell. A short heavy line represents the negative terminal and a longer lighter line the positive terminal.

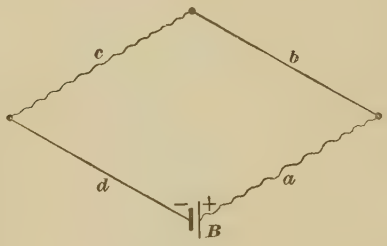


FIG. 4

29. Parallel, or Multiple, Connections.—A circuit that is divided into two or more branches, each branch carrying part of the current, is a parallel, multiple, shunt, or divided circuit, and the separate branches are connected in parallel, in multiple, or in shunt. Fig. 5 shows a divided circuit consisting of a source of electromotive force, B and conductors a, b, c, and d. Conductors b and c afford two current paths between the conductors a and d, and are therefore, in parallel. Either path b or c can be opened without interfering with the flow of electricity through the other path, because each is independent of the other. The arrows indicate direction of current. The total current in a parallel circuit is the sum of the current in the various branches.

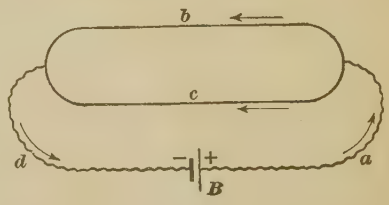


FIG. 5

30. When devices are connected in several series and these series are connected in parallel, as in Fig. 6, the devices are said to be connected in parallel-series, or multiple-series. *Series-parallel connection* means literally a series of parallels, as

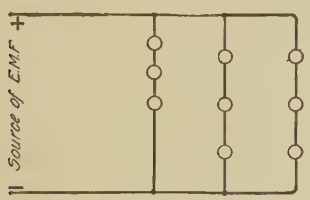


FIG. 6

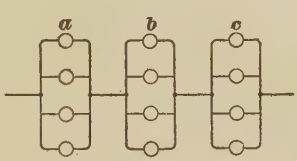


FIG. 7

indicated in Fig. 7, in which three groups *a*, *b*, and *c* are connected in series, each group having four devices in parallel.

The small circles of Figs. 6 and 7 represent the customary way among electricians of indicating filament lamps, such as Mazda lamps, in wiring diagrams.

31. Switch.—A switch is a device for opening and closing an electric circuit. If it opens or closes the circuit in only one place, as in Fig. 8 (*a*), it is a single-pole switch; if it opens or closes both parts, or sides, of the circuit, as in (*b*), it is a two-pole, or double-pole, switch. In speaking of opening or closing circuits, the trade words *break* and *make* are often used to convey the same meaning. A cut-out is essentially an automatic device that opens a circuit when the current becomes too great.

32. Grounded Circuit.—An electric circuit is said to be grounded when any part of it is either intentionally or acci-

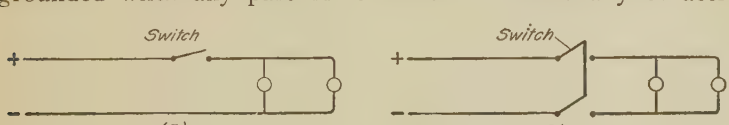


FIG. 8

dentally in electrical connection with the earth or with a conductor leading to the earth.

33. Short Circuit.—A short circuit is a path of very low resistance between two points having a difference of potential.

For example, if two bare wires leading to a lamp should become crossed, or touch each other, a short circuit would be formed, and the lamp would be short-circuited.

VOLTAGE DROP AND ENERGY LOSS

34. In an electric circuit the total drop of potential, or *voltage drop,* is equal to the electromotive force necessary to maintain current in the circuit against the various opposing forces in the circuit. For example, imagine a source of electromotive force developing 230 volts supplying current through wires to an electric motor. Some of the electromotive force, say 10 volts, is used in overcoming the resistance of both wires of the circuit, and the remainder, 220 volts, is available at the motor terminals. The voltage drop in the two wires of the circuit is 10, and the drop in the motor is 220.

35. The voltage drop in conductors can be calculated if the length of the wire, the current, and the cross-sectional area of the wire in circular mils are known by using the formula

$$\text{voltage drop} = \frac{10.8 \times l \times I}{a}$$

in which 10.8 = resistance, in ohms per foot, of copper wire one mil in diameter;

l = length of wire, in feet;

I = current, in amperes;

a = cross-sectional area of wire, in circular mils.

36. Voltage drop in conductors leading to electric motors, lamps, and so forth, serves no useful purpose, and, when multiplied by the current and time, equals the energy wasted in heating the conductors. It is, therefore, desirable to make the drop low, not only for economy in transmission, but also to prevent overheating the conductors. In order to keep the voltage drop down, the wires must be of minimum length and of maximum diameter. But the length l is usually fixed by the location and size of the buildings to be wired and the current I is determined by the number and size of the devices to receive current. Furthermore, wires must be selected to comply with the rules of fire-

insurance underwriters and with city ordinances. Because of the heating effect of the electric current and the resulting fire hazard, insurance underwriters and many cities have prescribed rules limiting the quantity of current in each standard size of wire.

37. The engineer must provide himself with a copy of the National Electrical Code of Rules, which can be obtained through any general insurance agency, and a copy of the ordinances of his city. Having determined the current to be carried, he must then select wires no smaller than are called for by these rules and check the sizes by the formula of Art. **35** so as to be sure that the voltage drop is not greater than the difference between the voltage at the source of the electromotive force and the voltage required at the terminals of the lamps or motors to be fed. The calculation may show the need of selecting a conductor larger than is prescribed by the rules, and this is often the case for long circuits.

PRIMARY MAGNETIC DEFINITIONS

38. In Magnesia, a province of ancient Greece, a substance was found many years ago that had the peculiar property of attracting to itself pieces of iron. The name of the province suggested the name *magnet* for the substance and later the discovery was made that pieces of steel can be *magnetized* so that they exhibit the same peculiarity. The names *natural magnets* and *artificial magnets,* therefore, came into use. Natural magnets are very rare and are of no practical use, but artificial magnets are an important part of many electrical devices.

Materials capable of being magnetized are magnetic, and, of these, iron and steel are most important. Soft iron when brought close to a magnet is magnetized temporarily, but loses its magnetism when the two are separated. Steel, however, when magnetized, retains its magnetism, and thus becomes a permanent magnet.

In every magnet are two points, called *poles,* that exhibit opposing characteristics. For example, in a magnetized steel bar, or *bar magnets,* the poles are at the ends, and if two such

magnets are brought near each other, one pole of one magnet will either attract or repel one pole of the second magnet, but will have exactly the opposite effect on the other pole.

39. Around every magnet is a space, or field, called the *magnetic field,* within which the magnet exhibits its power to attract or repel. Any piece of magnetic material, such as iron or steel, when in a magnetic field, becomes a magnet with poles in opposite positions from those of the magnet causing the field. In other words, magnetism is induced in such material, and this magnetism has direction, or is along certain lines called *lines of force.* All the lines of force of a magnet combined are called the *flux* of the magnet, or the *magnetic flux.*

Magnetic lines of force pass out of the north pole of the magnet and enter the south pole, passing through the magnet itself from the south pole to the north pole. A point near the north geographical pole is called a north magnetic pole, but, in reality, if the magnetic rules are applied to the earth's magnetic pole, the magnetic pole situated near the north geographical pole would be known as a south magnetic pole, and the magnetic pole situated near the south geographical pole, a north magnetic pole. Since the lines of force pass through a magnet from the south pole to the north pole, the lines of the earth's magnetic field would pass from near the north geographical pole, through the earth, to a point near the south geographical pole, from there out through the atmosphere to the magnetic pole near the north geographical pole. Any magnet that is placed in line with a magnetic field will turn so as to have the magnetic lines pass into its south pole, and out of its north pole, the magnetic lines passing through the steel of the magnet itself from the south magnetic pole to the north magnetic pole. The north pole of the compass needle, or the north-seeking pole, points toward the magnetic pole situated near the north geographical pole.

40. Every conductor carrying an electric current is surrounded by a magnetic field. The effects of this field are maximum in the space next to the conductor, the effects decreasing as the distance from the conductor increases. The magnetism thus established by an electric current is called *electromagnetism.*

GENERATORS AND MOTORS

41. Electromagnetic Induction.—Electromagnetic induction is the action by which an electromotive force is established in a conductor by the influence of a magnetic flux. If a conductor be moved in a magnetic field so as to cut across the lines

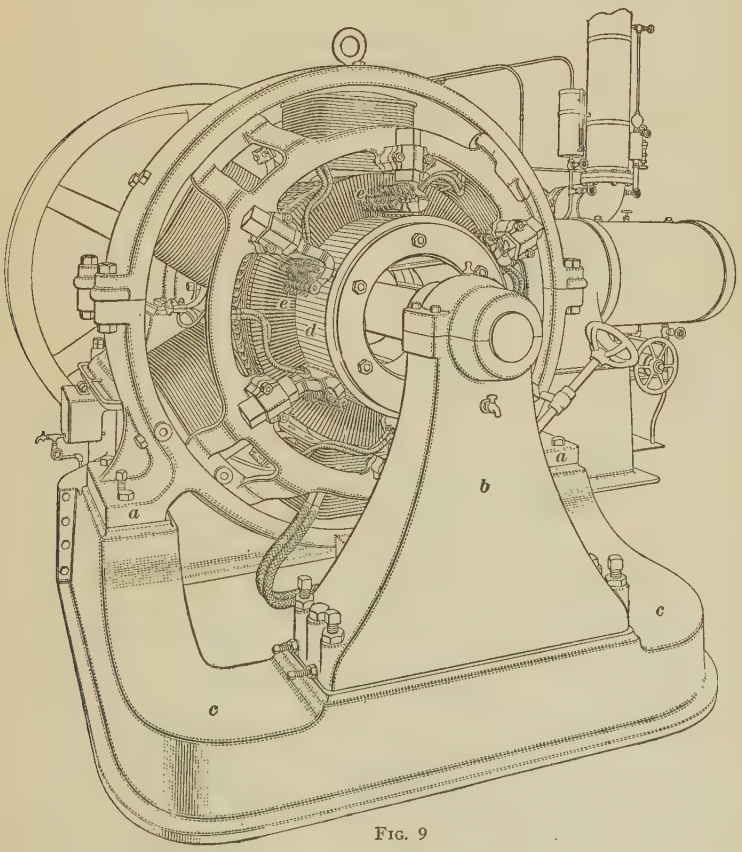


FIG. 9

of force, an electromotive force will be set up in the conductor, and, if the conductor be part of a closed circuit, an electric current will flow in it. The same effect will be produced if the conductor be held stationary and the magnetic field be in motion; it is only necessary that there be between the two relative

motion such that lines of force are cut by the conductor. The direction of the induced electromotive force depends on the direction of the lines of force, or polarity of the magnetic field, and on the direction of motion; a reversal of either polarity or motion reverses the electromotive force.

42. Electric Generator.—The principle of electromagnetic induction is used in the electric generator, which is a machine for converting mechanical work into electrical work. A direct-current generator, which, as the name implies, is a machine for developing direct-current electricity, has a stationary field magnet and a revolving armature that carries the conductors in which the electromotive force of the machine is generated. In revolving, each conductor on the armature passes under a north pole and a south pole alternately. The direction of electromotive force therefore alternates, and, in order that a direct current may be delivered, a device called a *commutator* is necessary. Current is collected from the revolving armature by stationary brushes bearing on the commutator. The commutator and the brushes are so arranged that the connection of the external circuit to the armature conductors is reversed at each instant that the current in the conductors reverses, so that each brush collects current passing in only one direction.

43. In Fig. 9 is shown a direct-current generator connected directly to a reciprocating steam engine; *a* indicates the feet of the generating frame, *b* the bearing pedestal, *c* the bedplate, *d* the commutator, and *e* the armature. The word *dynamo* is sometimes used in referring to a direct-current generator.

44. Direct-current motors are the same in elementary respects as direct-current generators, but they differ in mechanical design because they are required to perform a different service. Properly timed attractions and repulsions between the field magnet and the armature cause the rotation.

ELEMENTARY ALTERNATING-CURRENT DEFINITIONS

45. Principle of Alternating-Current Generator.—Because the armature conductors of a generator pass a north pole and a south pole alternately, the electromotive force generated therein is alternating. If the commutator of a direct-current generator be replaced by a pair of rings insulated from everything except the circuits of which they are parts, the electromotive force between the rings will be alternating, and a current in an external circuit connected to the rings through brushes will also be alternating. This is the principle of the alternating-current generator, more frequently called an *alternator.*

46. Generator Comparison.—A primary difference between an alternator and a direct-current generator is that the former needs no commutator. The alternating current of the armature winding can pass directly to the external circuit, and, therefore, the armature can be made the stationary member of the machine. In fact, most alternators are constructed with the armature the stationary member, or *stator,* and the field magnet the rotating member or *rotor.*

47. The electromotive force generated by an alternator —in other words, an alternating electromotive force—rises from zero to a maximum value in what is arbitrarily called a positive direction, falls to zero, rises to a negative maximum, falls to zero again, and so on repeatedly, as long as the alternator is in operation. There is a continually recurring set of values, half positive and half negative, and one such set is called a *cycle.* An alternation is one-half cycle; conversely, a cycle is two alternations. The number of cycles per second is called the *frequency.*

POLYPHASE ALTERNATING CURRENTS

48. Single-Phase System.—If an alternator has only one armature winding, all the armature conductors act together to set up one electromotive force and one current, called a *single-phase electromotive force* or a *single-phase current,* respectively. The circuit that carries the current is called a *single-phase cir-*

cuit and the alternator is called a *single-phase alternator.* Such an alternator is said to have a single-phase winding. But it is possible to equip an alternator armature with two or more windings with the conductors so arranged that the electromotive forces and the resulting currents have definite phase relations with one another. The winding, the alternator, the electromotive forces, the currents, and the circuits are then designated as *polyphase,* and each is a part of a polyphase system.

49. Polyphase System.—Fundamentally, a polyphase system is a number of single-phase systems properly combined. The polyphase system may have a pair of conductors for each single-phase element; or some of the conductors may be omitted and those remaining may be made to act in common for all the single-phase elements. The current in any of these common conductors is not equal to the arithmetical sum of the single-phase current, but is less, because of the phase differences among the currents.

50. The only two commercial polyphase systems of practical importance are the *two-phase system* and the *three-phase system.* In the former the alternator windings are arranged so that two currents are established which are one-fourth of a cycle apart in phase. Usually four wires are employed in the external circuit, so that the system is practically equivalent to two single-phase systems employing two wires each. In the three-phase system, the alternator windings are arranged so that three currents are established which are one-third of a cycle apart in phase.

ALTERNATING-CURRENT MACHINERY

51. Classification.—Alternating-current motors are divided into two broad classes, *single-phase motors* and *polyphase motors,* depending on whether they operate on single-phase current or on polyphase current.

52. Induction Motor.—An induction motor has a stator, or stationary member, sometimes called the *primary*; and a rotor, or revolving member, sometimes called the *secondary.* The

speed of an induction motor can be controlled with the aid of extra devices, but usually the motor runs at nearly constant speed under ordinary load conditions. It also can be made to start under load. Induction motors are made in sizes and designs adaptable to almost every kind of machine requiring mechanical drive. One of the many types of three-phase motors

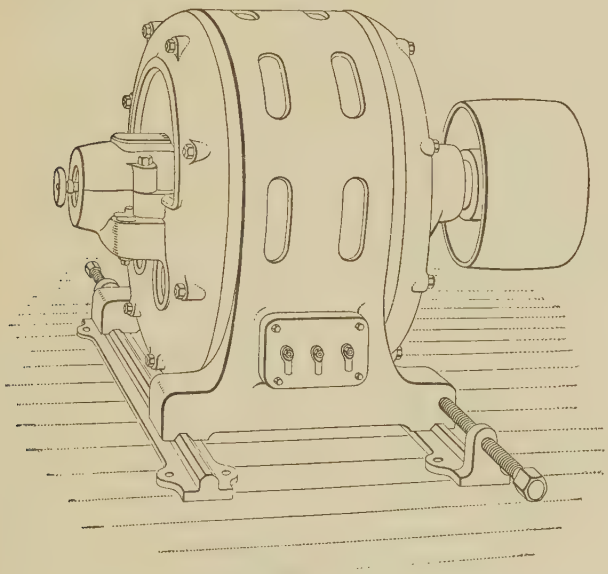


FIG. 10

is shown in Fig. 10. There is a limit, however, to the sizes in which single-phase motors can be made.

53. Transformers.—A transformer, sometimes called a *static transformer* because it has no moving parts, is a device for changing the voltage of alternating current circuits. A *step-up transformer* raises the voltage, and a *step-down transformer* lowers the voltage. Each transformer has two coils, both on the same iron core. Each coil is insulated from the other and from the core. The primary coil is the one that takes the current from a supply circuit, and the secondary coil is the one that supplies current to some other circuit or devices. One

is a low-voltage coil and the other a high-voltage coil. For economical transmission of electric energy over long distances the voltage must be high, and step-up transformers are generally used to raise it; from such a high-voltage system the voltage must again be stepped down by other transformers to the voltage permissible for interior wiring. The external appearance of a transformer is shown in Fig. 11. A bank of transformers is a combination of transformers connected together in place of a single large transformer.

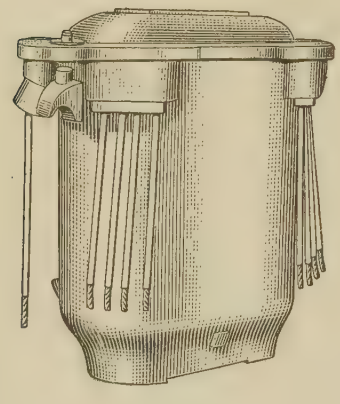


FIG. 11

54. A **rectifier** is, in general, any device for changing alternating current to direct current. One form is the mercury-vapor rectifier, so called because it utilizes a peculiar property of mercury in changing the current. The Tungar rectifier is used extensively for charging storage batteries for automobiles and signaling systems.

MISCELLANEOUS DEFINITIONS

55. The **load** on an electric generator, a battery, or on an electric system in general, usually means the power taken from the system, although the term is sometimes applied to current. An **overload** is a load that is greater than the system is designed to handle.

56. A **storage cell** is a device for converting electrical work into potential chemical energy, and holding it available for return as electrical work. A storage battery is a combination of storage cells.

57. A **motor-generator** is a generator driven by a motor. The generator and the motor are usually mounted on the same bed-plate, and both of the rotors are on the same shaft. Motor-

generators are used for converting alternating current into direct current, or vice versa, and for changing the voltage of direct current.

58. A **switchboard** is a place for mounting switches and other devices required for controlling a number of electric cir-

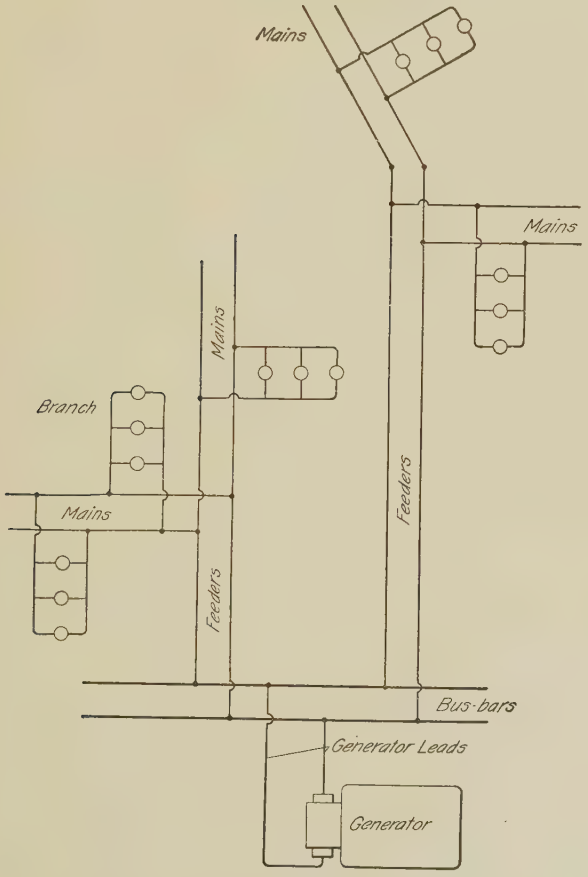


FIG. 12

cuits. The switchboard usually bears the proper measuring instruments also. The switchboard is the heart of the control system of a large interior wiring installation. There the entire

system, or any part of it, can be disconnected from the source of electrical supply.

59. A **bus-bar,** or **bus,** on a switchboard is a conductor mounted on the back of the board, and so connected with switches that by operating a switch any one or more of several circuits may be connected to the bus-bar or disconnected from it at will. Usually at least two bus-bars are required for the ordinary interior circuit.

60. A **feeder** is a part of a system that carries current for a number of other circuits or parts of the system. A feeder serves as a trunk. A **main** is practically a continuation of a feeder, but carries less current and is made up of smaller conductors. A **feeder-and-main system** is similar to a tree, and is sometimes called a tree system; the feeder is the trunk, the mains are the branches, and the small circuits, or branch circuits, correspond to the twigs of the tree.

61. In Fig. 12 are illustrated the main essentials of a distributing system for electricity. The diagram shows the fundamental relations of bus-bars, feeders, mains, and branch circuits. The illustration also shows one of the conventional methods of representing direct-current generators or motors on wiring diagrams.

62. A **relay** is a device for closing or opening an electric circuit, as the case may require, when predetermined conditions in another circuit take place.

63. A **magneto** is a small alternating-current generator with a field formed of permanent magnets, and a rotating armature with a large number of turns of fine wire. A magneto is used chiefly for testing and in telephone systems.

NATIONAL ELECTRICAL CODE

64. Origin and Purpose.—When electricity began to come into general use, electric wiring in buildings was installed with little regard to safety, and many disastrous fires resulted. Soon fire underwriters refused to insure buildings unless the wiring was considered safe, and the preparation of a set of safety standards became necessary. In 1897 a national conference of delegates representing various insurance, electrical, architectural, and allied interests in the United States proposed the National Electrical Code, which was at once adopted by the National Board of Fire Underwriters. The Code is now in charge of the National Fire Protection Association and is accepted as standard not only by underwriters but by many state and municipal governments and by various organizations of public service corporations, professions, manufacturers, and trades interested in the design or the construction of buildings.

The Underwriters' Laboratories located in New York and Chicago test the various materials and devices that are used in electrical construction, and they also publish a "List of Inspected Electrical Appliances" which they have found by tests to comply with the standards of the Code.

65. Special Rules.—In many of the large cities, the installation of the electric wiring is governed by municipal ordinances. The Electrical Service Companies also have rules that must be observed before they are permitted to make connections to the supply mains.

66. Inspections.—Each local board of fire underwriters has inspectors who examine and test the electrical work of buildings at certain stages of its progress and also after the building has been completed, to determine if the rules of the code have been complied with. A certificate of approval is issued by the underwriter when the completed work is found to meet these requirements. Where municipal ordinances are in force, the work must be installed to conform with these requirements and a certificate is issued by the city when the work has been approved.

67. Advantages of Code.—The National Electrical Code and the List of Inspected Electrical Appliances provide standards by which architects and contractors can plan and execute work that will meet the requirements of the Underwriters when insurance is desired. For buildings on which no insurance is contemplated, it will also prove a practical and reasonable investment to have the work installed in conformity with these standards, as it will greatly reduce the fire hazard. It is, therefore, very important that the architect and contractor be thoroughly familiar with both the Code and the List of Inspected Electrical Appliances and install work that will conform with these requirements. Copies of the Code and the List of Inspected Electrical Appliances may be obtained from any local office of the Underwriters, or from the New York or Chicago Underwriters' Laboratories.

68. If the building is located in a city, inquiry should be made to learn the requirements of the municipal ordinances and the company furnishing the electrical power. Architect's specifications usually stipulate that all electrical work and materials shall conform with the code standards and the city ordinances, and that certificates of approval shall be obtained from the underwriters and the city before the final payment is made to the electrical contractor. The inspection and approval of the electrical work by persons familiar with all details of electrical installation are evidence of a good job and are essential to the obtaining of the minimum rate for insurance, should the owner desire to insure the building.

WIRING FOR LIGHT AND POWER

DISTRIBUTION SYSTEMS

FUNDAMENTAL SYSTEMS

69. An electrical-distribution system comprises all the conductors and all the apparatus necessary to take electricity from a source of supply and deliver it in proper form for utilization at various electrical devices. Practically all distribution systems for interior wiring are parallel systems; the conductors and the apparatus are connected in parallel.

70. The two fundamental systems are the direct-current system and the alternating-current system. They are also classified as low-tension systems and high-tension systems, depending on the voltage of distribution. From the architect's viewpoint, a complete distribution system can be divided into two parts, the outside system, by which electricity is brought to a building, and the interior system, by which it is distributed throughout the building. Practically all American systems are constant-potential systems, so called because the voltage at the consuming device remains practically constant.

71. Constant-potential systems of 600 volts or less are classed by the underwriters as low-potential systems, those of 601 to 5,000 volts, as high-potential systems; and those of over 5,000 volts as extra-high-potential systems. As a general rule, voltages above 250 are seldom used in buildings other than those of an industrial character. Where high voltage is used, however, the apparatus should be enclosed by means of a wire screen or a railing, to provide ample protection against a person accidentally coming in contact with the devices and being seriously injured.

72. Direct-current systems employ either two or three wires as conductors, and are know as *two-wire systems* and

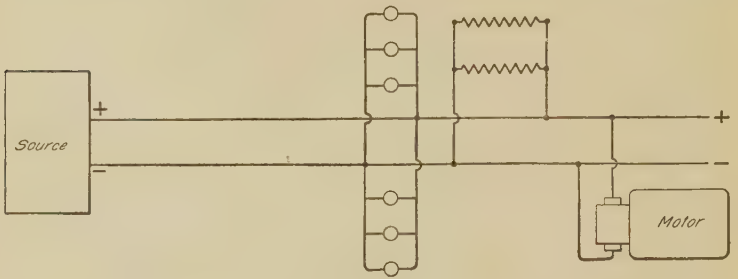


Fig. 13

three-wire systems, respectively, as shown in Figs. 13 and 14.

The neutral wire of a three-wire system is usually placed in the center and the pressure between this wire and either outside wire is one-half the pressure between the outside wires. In diagrams the neutral wire is generally indicated by the ± sign, as shown.

73. Several alternating-current systems are in use for interior wiring, namely, the single-phase two-wire system for which the diagram is the same as for the direct-current two-wire system, Fig. 13; the single-phase three-wire system with connections as shown in Fig. 14; the two-phase four-wire system, Fig. 15,

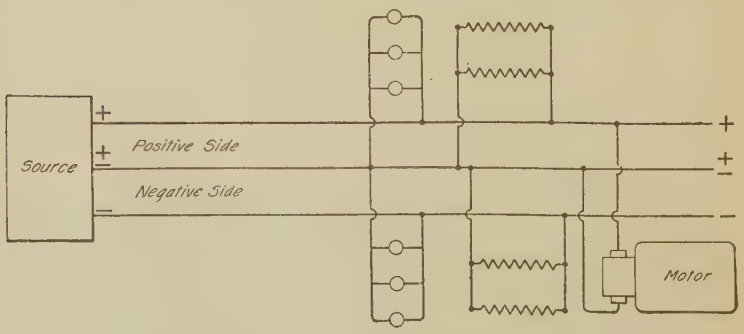


Fig. 14

which is practically equivalent to two single-phase two-wire systems; the two-phase, three-wire system, Fig. 16; the three-phase,

three-wire system, Fig. 17, and the three-phase four-wire system, Fig. 18.

A simple three-phase system would have six wires, two for

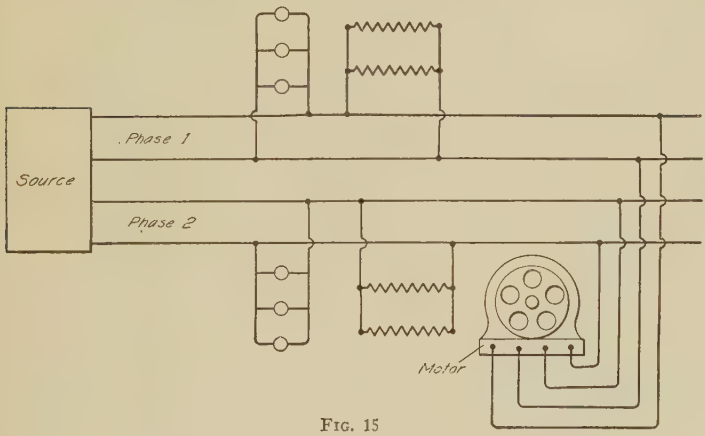


FIG. 15

each phase, if it were not for the time-phase relations of the voltages and currents, which permit one wire of each phase to be eliminated, each of the three remaining wires acting in turn as the second wire for each of the other two phases.

74. The three-phase, three-wire system illustrated in

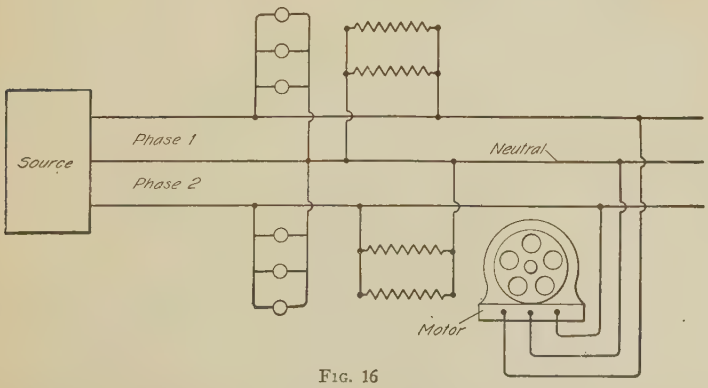


FIG. 16

Fig. 17 is the result of such an arrangement. A two-wire circuit can be connected across any two wires of the system. A

two-wire circuit is then, in effect, a single-phase alternating-current system deriving its energy from the three-phase system.

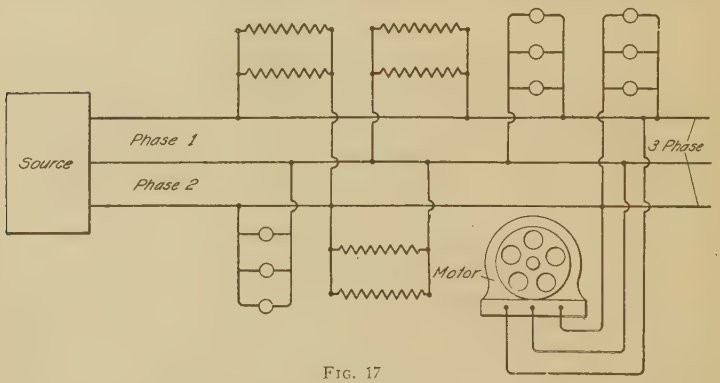


FIG. 17

Single-phase circuits thus tapped from the three-phase system are connected so as to keep the three-phase system as nearly as

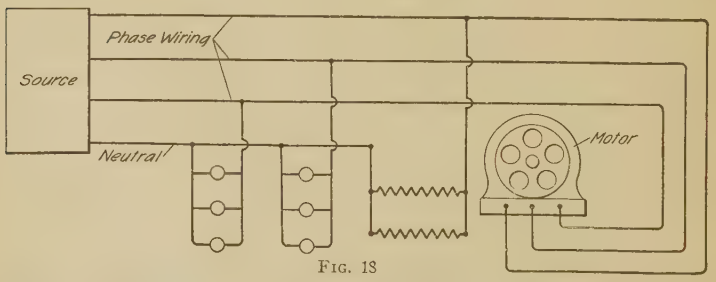


FIG. 18

possible in balance. Three-phase motors use all the wires of the system, as indicated in the diagram.

COMMERCIAL SYSTEMS

75. Choice Between Direct and Alternating Current.—Any installation of interior wiring must be planned according to the kind of electricity available in the locality. If the energy is to be taken from lines of the local light and power company, as is generally the case, the characteristics of the current can be learned from that company.

76. Direct-Current Energy.—If the designer is free to choose the kind of energy, he must decide first between direct-current and alternating current. This is a problem which should be referred to an electrical engineer if the work is extensive or the requirements complex. For general information, however, it is desirable to know that direct-current energy is essential for some purposes such as storage batteries, electrolytic work, and operating some kinds of lamps. It is also preferable to alternating current for operating motors on hoists, cranes, or other machinery.

77. Alternating-Current Energy.—For motors that must run at very nearly constant speed under all conditions of load and temperature, as in driving textile machinery, alternating-current energy is essential. This requirement may demand such energy, even though the distribution covers a very small area. If such energy is purchased, the following information should be obtained from the central station: System of inside wiring recommended, number of phases, and number of wires; service voltage, or voltage at which current will enter the building; manner in which company's wires will enter building, overhead or underground; location of transformers.

78. When installing a private generating plant, there is opportunity to choose an alternating-current system best adapted for the purpose to be carried out. The single-phase system affords the simplest form of alternating-current distribution, and is much used, especially where the load is composed either entirely or very largely of lamps. Many single-phase motors are in use in capacities up to 10 horsepower, inclusive, and are practically equal to polyphase motors in starting and operating characteristics, although some complications in construction are necessary in order to obtain good starting effort.

79. Two-phase systems are not so commonly employed as three-phase systems. The three-wire three-phase system is particularly applicable where the amount of lighting is small compared with the amount of motive power used. Single-phase lighting from three-wire three-phase mains is unsatisfactory when many lamps are in use, unless the load is so carefully bal-

anced that the voltage regulation will not be disturbed. The four-wire three-phase system is better where both lamps and motors are in use, because the voltage regulation is better.

FEEDER-AND-MAIN SYSTEM

80. Service Mains.—When electricity is purchased from a light and power company, service leads, or service mains, leading to the consumer's premises are installed by the central-sta-

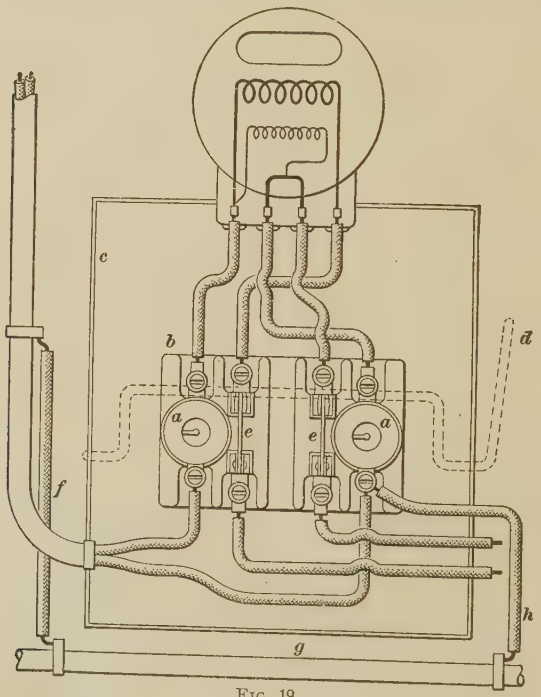


FIG. 19

tion men to carry current from the central-station distribution system to the interior wiring of the building, as indicated in Fig. 19, which shows the service connections for a two-wire installation in a small residence. In practice, the switch and the cut-out, consisting in this case of fuses *a* mounted on a porcelain base *b*, are customarily placed in a metal box or cabinet *c*, with a handle on the outside of the box, as shown by the

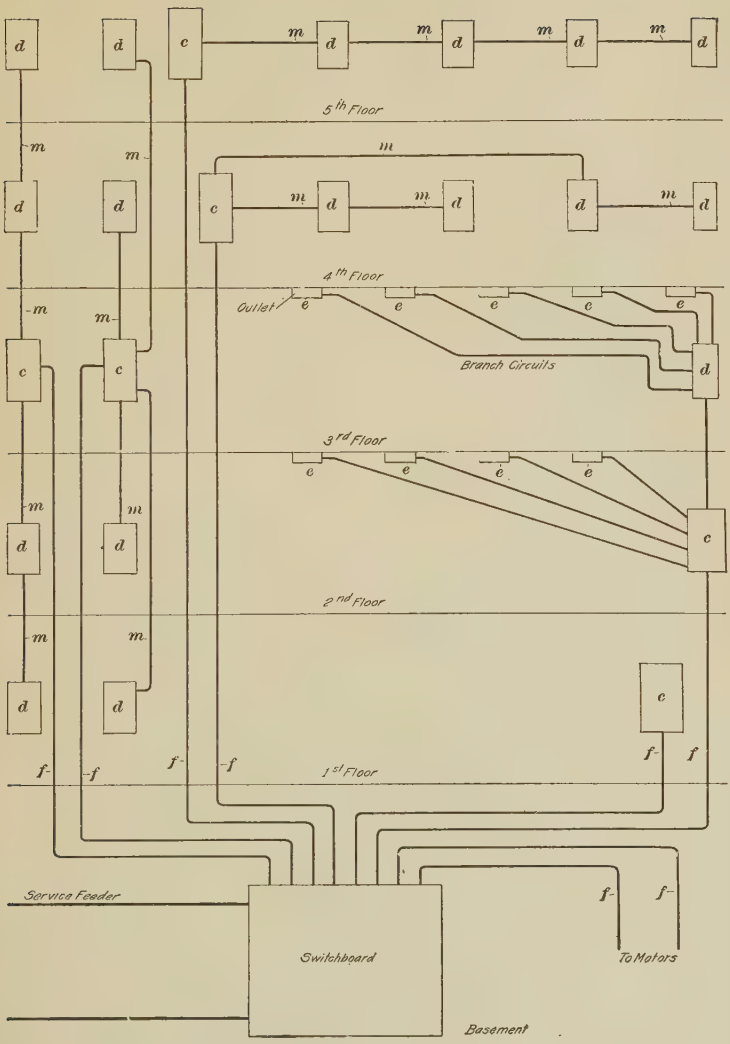

5th Floor
4th Floor
Outlet
Branch Circuits
3rd Floor
2nd Floor
1st Floor
Service Feeder
Switchboard
To Motors
Basement

FIG. 20

dotted lines *d*, to operate the switch blades *e*. The service conduit is grounded at *f* to a water pipe *g*, and one side of the circuit is grounded through *h* to the same pipe.

81. Purpose of System.—The feeder-and-main system is almost invariably followed in wiring large installations, and is applicable to either direct- or alternating-current systems. The service feeder from the outside distribution system is carried to a switchboard, Fig. 20, on which are mounted the central-station company's meters and the service switches. This switchboard serves as the main center of distribution for the building. From the switchboard, trunk conductors, or feeders shown at *f* are carried to distribution centers *c*, from which smaller trunks, or mains *m* run to other distribution centers *d*, and from these are carried the branch circuits *e* to which the electrical appliances are connected. If the wiring is concealed, the appliances are connected at outlets, the points at which the wiring is brought to the surface. From some distribution centers, both mains and branch circuits may be run, as shown at the right in the illustration, while some feeders may supply branch circuits only, as conditions may require. Large motors require separate feeders. A vertical feeder or main is called a *riser*.

The layout shown is not intended to represent an actual installation. It is designed chiefly to show the different methods of connecting circuits. In this layout branch circuits are shown from only two of the distributing centers, but in the actual installation branches are taken from each center.

WIRES AND CABLES

TERMINOLOGY

82. A **wire** is defined by the U. S. Bureau of Standards as a slender rod or filament of drawn metal. An **insulated wire** is one covered with an insulating material. A **stranded conductor** is one composed of a group of wires, or any combination of groups of wires. The word *strand*, as commonly

used, may refer to one of the wires or to one of the groups of wires making up the conductor of a cable.

The word *cable* is usually applied to the larger conductors, especially if stranded, while the smaller conductors are known as *wires* or *cords*.

Single-conductor cable is the name usually given to a cable consisting of one stranded conductor. A *multiple-conductor cable* is a combination of conductors insulated from one another. *Duplex cable* is frequently called *two-conductor,* or *two-wire, cable; triplex cable* is called *three-conductor,* or *three-wire cable.*

A duplex cable is a cable composed of two stranded conductors twisted together, and should be distinguished from a *twin cable,* which consists of two insulated stranded conductors laid parallel in a common covering. The duplex cable is a convenient and much-used form of cable.

Cord, commonly called *flexible cord,* is the name generally applied to a small, very flexible, insulated cable designed to withstand wear well.

A **twisted pair** consists of two small insulated conductors twisted together, without a common covering.

Twin or **duplex wire** is made up of two small insulated conductors laid in parallel in a common covering.

83. As indicated by the foregoing definitions, wire terminology is employed somewhat loosely because of the large variety of wires and cables necessary to meet so many applications. If an electrician needs to be explicit in mentioning a large-size conductor, if he means a solid conductor, he says (referring to a wire-gauge number) *number two-nought wire,* or, if he means a stranded conductor, *number two-nought cable.* In mentioning a smaller size, he says *number ten wire* or *number ten stranded,* as the case may require. In this Section the word *wire* when used in the collective sense or in the plural is understood to include all conductors, either wires or cables, and their insulation.

WIRE UNITS AND GAUGES

84. Mil.—The unit commonly employed to measure the diameters of wires for electric conductors is the mil, equal to .001 inch. The unit or area is the circular mil, the area of a circle with a diameter of one mil.

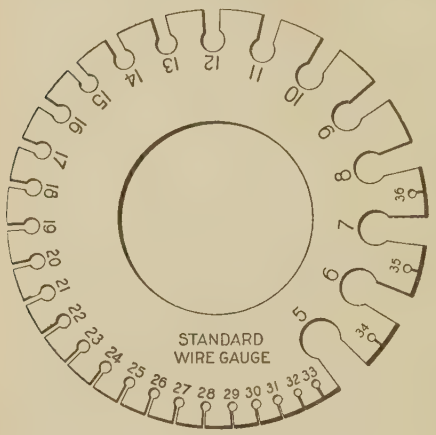


FIG. 21

85. Diameter of Wires.—Wires for commercial use are made with certain standard diameters, each diameter usually being specified by a gauge number. Of the several systems of gauge numbers used in the United States the most common is the American, or Brown and Sharpe (usually written B.&S.). The largest wire with a B. & S. gauge number is 0000 (pronounced *four nought* and frequently written 4/0), having a cross-sectional area of 211,600 circular mils. Larger conductors are designated by giving their areas in circular mils. In either case the dimensions are for the bare conductor only, the

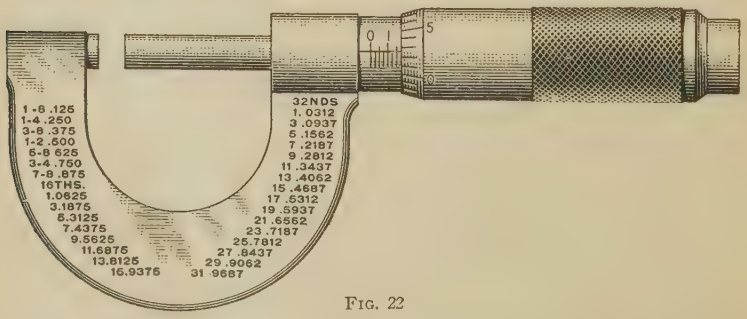


FIG. 22

covering not being included. The size of a solid conductor, or wire, is most conveniently measured by means of a wire gauge,

one form of which is shown in Fig. 21. To measure accurately the diameter of a stranded conductor, or cable, a micrometer caliper, Fig. 22, is necessary. Although aluminum has been used to some extent, refined copper of the highest obtainable commercial conductivity is almost always employed for conductors installed in buildings.

INSULATION

86. Rubber-covered (R.C.) wire or cable has an insulation of rubber compound of approved thickness covered by one or two outer protective braids. Conductors with slow-burning weather-proof (SBW) insulation have a single braid impregnated with a water-resisting material next to the conductor and one or two outer braids impregnated with a fire-resisting material. Slow-burning (SB) insulation consists of three or more braids impregnated with fireproofing material, the outside braid being specially designed to withstand abrasion.

Weather-proof (WP or Wp) insulation consists of at least three braids, all saturated with a moisture-proof insulating compound. Weather-proof wire is for use outdoors, where moisture is certain and where fireproof qualities are not necessary.

The insulation and the protective covering of flexible cord depends on the use to which the cord is to be put, and the specifications are fully covered by the Code.

Fixture wire is for use for inside electric fixtures, and may be either approved cord or approved rubber-covered wire, except where the wire may be subjected to a temperature higher than ordinary.

87. Lead-covered wires or cables are rubber-covered conductors having, in addition to the usual insulation and protection, a continuous lead sheath. Other names in frequent use are *lead cable* and *leaded wire*. The sheath of metallic lead is employed to give added protection from abrasion and moisture in places such as underground ducts. The lead also serves to protect the insulation from the action of chemical fumes, and is, therefore, useful in many industrial plants.

WIRE TABLES

88. Information that will be helpful in the selection of conductors for interior wiring is given in Tables I and II, the first table listing flexible cords in common use and the second giving the carrying capacities of standard conductors. Amperages greater than those listed in Table II are not considered safe, as the heating effect will cause the rubber insulation to deteriorate. For this reason, a lower current is specified for a conductor having rubber insulation than for one of the same size which has greater heat-resisting properties. Rubber-covered wire is generally used for interior work.

89. Sizes of Wires.—The smallest wire of the B. & S. system is No. 40, with a diameter of 3.145 mils; but wires smaller than No. 18 are not permitted in interior wiring, except as strands. The Nos. 16 and 18 wires are permitted in cords and in fixture wiring; other wires must not be smaller than No. 14. Solid conductors as large as No. 8 may be used, but for conduit work conductors of this size and larger are more easily handled if stranded. The size of the strands depends on the size of the conductor and the conditions under which it is to be used. Some engineers require that no conductor smaller than No. 14 shall be used on a job, even in fixtures; that no conductors smaller than No. 12 shall be used for other work; and that all conductors larger than No. 10 shall be stranded.

90. Inspection of Wire.—Approved wire bears the inspection stamps of the Underwriters' Laboratories and usually has a system of colored threads woven into the braided covering to identify the wire and also serve as a manufacturer's trade-mark.

TABLE I

FLEXIBLE CORDS

Use	Type	Trade Name	Branch on Each Conductor	Reinforcement or Filler	Outer Cover
As pendents or portables in dry places.....					
Where not subject to hard usage	*C* *PD* *PO*	Lamp cord Twisted portable Parallel cord	Cotton or silk Cotton or silk Cotton or silk		Cotton or Silk Cotton or Silk
For Hard Usage.....	*P* *CA* *PA*	Reinforced cord Armored cord Armor reinforced cord	Cotton or silk Cotton or silk Cotton or silk	Rubber Jacket Rubber Jacket	Cotton or Silk armor Cotton and armor
Pendents damp places..	*CB* *CC*	Brewery-cord Canvasite cord	Cotton Wp. Cotton Wp.		Cotton Wp.
Portable damp places....	*P Wp.* *Pk Wp.* *PA Wp.*	Reinforced cord Wp. Packinghouse cord Armor reinforced cord Wp.	Cotton Cotton Cotton	Rubber Jacket Filler. Rubber Jacket	Cotton Wp. 2 Cotton, both Wp. Cotton Wp. and armor
Theatre Stages	*T*	Stage cable	Cotton Wp.	Filler	2 Cotton, both Wp.
Theatre Borders	*B*	Border light cable	Cotton Wp.		2 Cotton, both Wp.
Elevator Lighting and control	*E*	Elevator cable	Cotton	Rubber Jacket and or	1 or more cotton both Wp. 3 Cotton, outer one Wp.

TABLE II

CARRYING CAPACITIES OF INSULATED WIRES

B. & S. Gauge Number	Sectional Area Circular Mils	Rubber Insulation Amperes	Other Insulations Amperes
18	1,624	3	5
16	2,583	6	10
14	4,107	15	20
12	6,530	20	25
10	10,380	25	30
8	16,510	35	50
6	26,250	50	70
5	33,100	55	80
4	41,740	70	90
3	52,630	80	100
2	66,370	90	125
1	83,690	100	150
0	105,500	125	200
00	133,100	150	225
000	167,800	175	275
0000	211,600	225	325
	200,000	200	300
	300,000	275	400
	400,000	325	500
	500,000	400	600
	600,000	450	680
	700,000	500	760
	800,000	550	840
	900,000	600	920
	1,000,000	650	1,000
	1,100,000	690	1,080
	1,200,000	730	1,150
	1,300,000	770	1,220
	1,400,000	810	1,290
	1,500,000	850	1,360
	1,600,000	890	1,430
	1,700,000	930	1,490
	1,800,000	970	1,550
	1,900,000	1,010	1,610
	2,000,000	1,050	1,670

CUT-OUTS AND SWITCHES

CUT-OUTS

91. Fuses.—In order to protect conductors from overload, short circuits, grounds, and so forth, it is necessary to place at

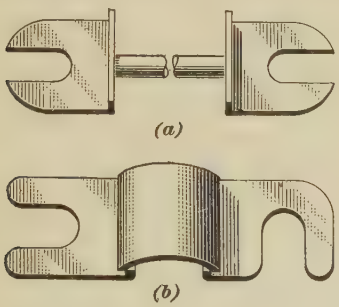


FIG. 23

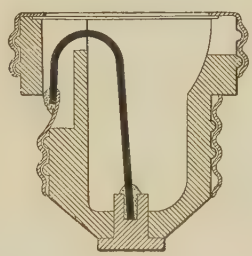


FIG. 24

proper locations in a circuit an automatic cut-out, which is a device for opening the circuit when the current exceeds the nor-

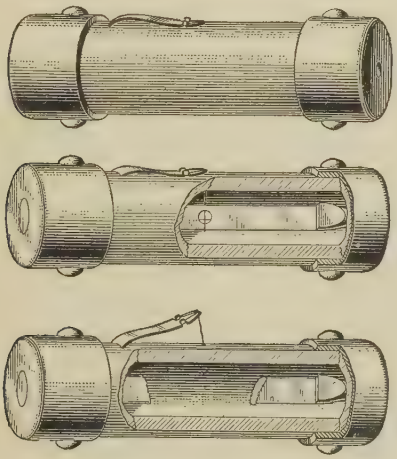


FIG. 25

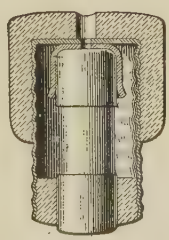


FIG 26

mal value. A cut-out may be either a fuse or a circuit breaker.

A **fuse** consists of a wire or a strip of alloy fusible at a comparatively low temperature, with copper terminals. An exces-

FIG. 27

sive current melts the fusible metal before the remainder of the circuit can be injured. A fuse so treated is said to be *blown*. The simplest form is the *link fuse*, two forms of which are shown in Fig. 23 (*a*) and (*b*).

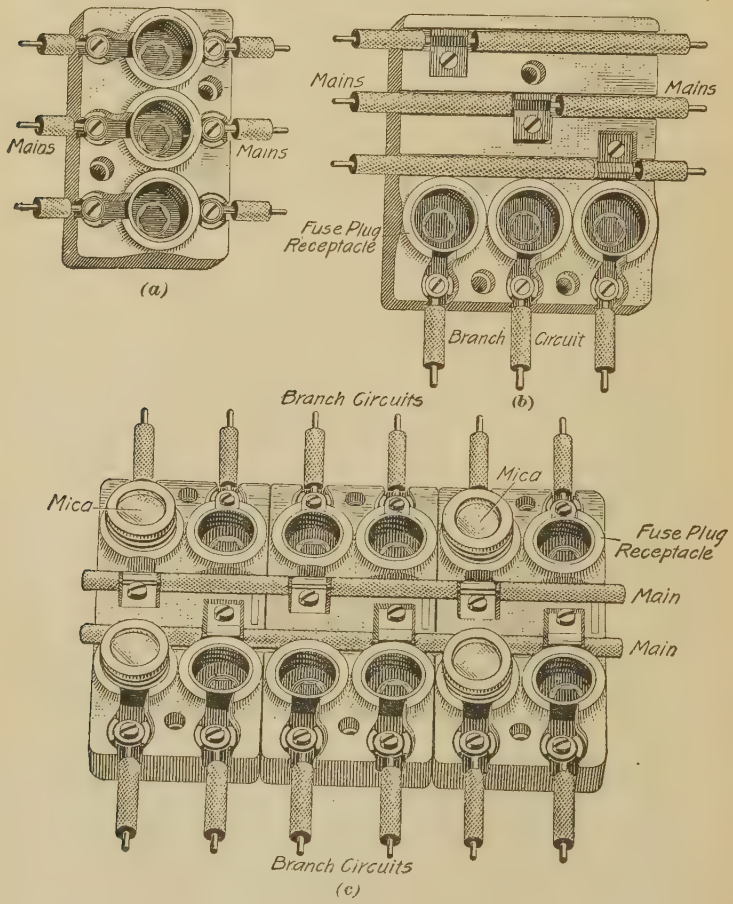


FIG. 28

A *plug fuse*, shown in section in Fig. 24, is made to screw into a receptacle in a manner similar to the ordinary electric lamp.

An example of the *enclosed fuse* known as the *cartridge fuse* is shown in Fig. 25. In Fig. 26 is shown an Edison plug adapted to a cartridge fuse.

A renewable fuse is a cartridge fuse in which the fusible metal strip can be replaced and the holder retained, as shown in Fig. 27.

Open, or link, fuses, have the great disadvantage that they cause an electric arc and the spattering of molten metal when they blow, so they are rapidly becoming obsolete.

Plug fuses are usually mounted on porcelain fuse blocks, three forms of which are illustrated in Fig. 28, (*a*), (*b*),

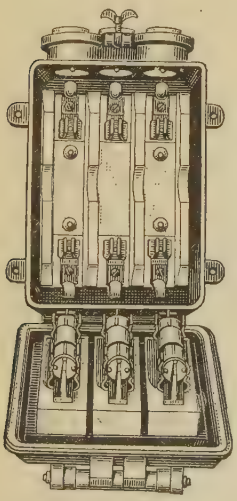


FIG. 29

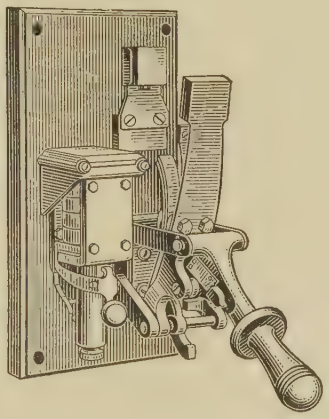


FIG. 30

and (*c*). Cartridge fuses also are sometimes mounted on open-fuse blocks. Fuse blocks are generally used for open wiring and for only the cheaper methods of concealed wiring.

92. In Fig. 29 cartridge fuses are shown mounted on porcelain blocks, or bases, in a steel fuse box. The fuse terminals are arranged so that by opening the box the circuit is opened, thus preventing danger from shock when replacing a blown fuse.

93. Circuit-Breakers.—Automatic circuit-breakers, one form of which is shown in Fig. 30, are electro-mechanical devices designed to perform the same offices as fuses. In principle a circuit-breaker is simply a special type of switch that can be opened either by hand or by the action of a current greater than that for which the breaker is set. They are used where heavy currents or high potentials are to be handled, as in power plants and industrial works, and on main switchboards in large buildings.

KNIFE SWITCHES

94. A knife switch is so called from the form of the contact-making arm, or blade, and the methods of making contact. A typical form of double-pole knife switch is shown in Fig. 31, and a triple-pole knife switch in Fig. 32. Such switches are commonly called *fused switches,* or *combination cut-out switches,* because fuse receptacles, or clips, *a* and *b*, Fig. 31, are mounted on the bases. The clips shown are to hold the cartridge type of fuse. Link fuses may be connected across the terminals *a* and *b*, Fig. 32. A fused switch is convenient and economical of space, because almost invariably cut-outs are required wherever a knife switch is required. The examples illustrated in Figs. 31 and 32 are single-throw switches because they close in only one direction. A double-throw switch is one that closes in either of two directions, as in Fig. 33, thus enabling the operator to connect a given circuit to either of two other circuits, or to connect a set of mains to either of two feeders.

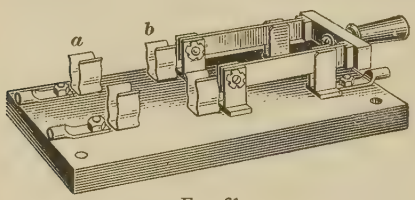


FIG. 31

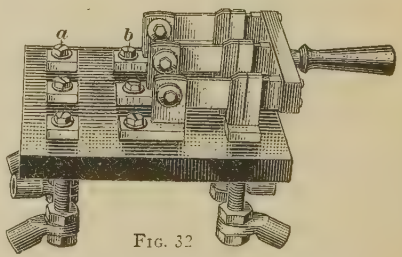


FIG. 32

The switch shown in Fig. 31 is a front-connected switch, as the lugs to which the wires are connected are on the same side

of the slate base as the switch lever. Back-connected switches have the connecting lugs on the opposite side of the base, as in Figs. 32 and 33. The switch illustrated in Fig. 33 is shown as it would be mounted on a slate panel of a switchboard. The connecting lugs are shown at *a*. Cartridge fuses are indicated at *b*.

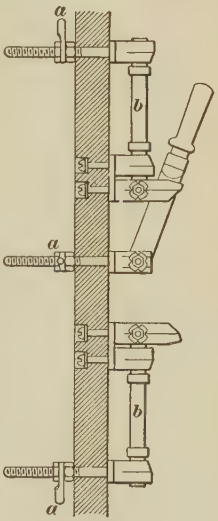


FIG. 33

95. Whenever a current is broken there is formed at the points of break a spark, or arc, the size and intensity of which depends under given conditions on the amperage and the voltage. The underwriters therefore recommend the mounting of individual switches in fireproof cabinets, or switch boxes, one type of which is shown in Fig. 34. In (*a*) is shown the complete box closed and locked. In (*b*) is the cover removed. In (*c*) is the interior of the box. Where wires are carried in metal conduits switch boxes must be made of metal not less than $\frac{3}{32}$ inch thick.

96. A special form of switch and switch box, the so-

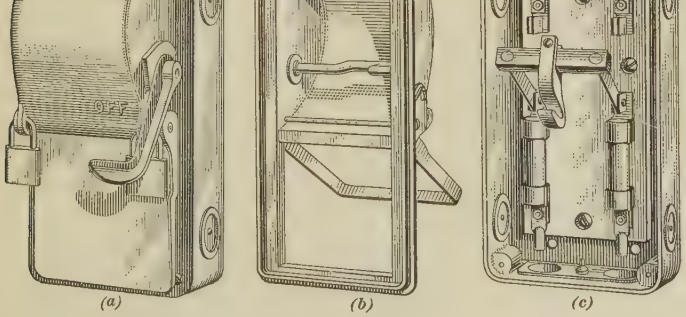


FIG. 34

called *safety-first enclosed lever switch,* is illustrated in Fig. 35 (*a*) and (*b*). The switch blades are operated by a handle that

can be moved without opening the box and that can be locked in position. All parts that carry current are enclosed and inac-

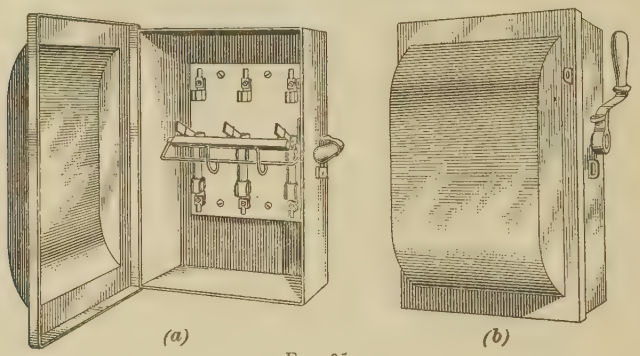


FIG. 35

cessible while the current is on. The fuses are accessible only while the switch is in the off position. The laws of some states make the use of these enclosed switches mandatory.

SNAP SWITCHES

97. For lighting circuits carrying as high as 30 amperes at voltages up to and including 250 volts, the underwriters suggest the use of approved snap switches, so called because the make-and-break action is controlled by means of a spring in such a way that the switch opens or closes with a snap, no matter how slow the movement of the operator. Snap switches are of two general types, flush switches and surface switches; and of three general forms of construction: push-button switches, rotary switches, and toggle switches.

A push-button switch of the flush type is shown in Fig. 36 (*a*) and (*b*). When mounted, the faceplate shown in (*a*) comes flush against the wall.

A rotary switch of the surface type is shown in Fig. 37 (*a*) and (*b*). The printed disk inside the case rotates with the key and the words *ON* and *OFF* appear at the small opening in the case.

A toggle switch is operated by a small lever protruding through the faceplate, Fig. 38. The switch is so named because

the snap action is secured by means of what is known as a toggle joint. Switch boxes for snap flush switches take the general form shown in Fig. 39.

98. When switches are placed side by side they are usually

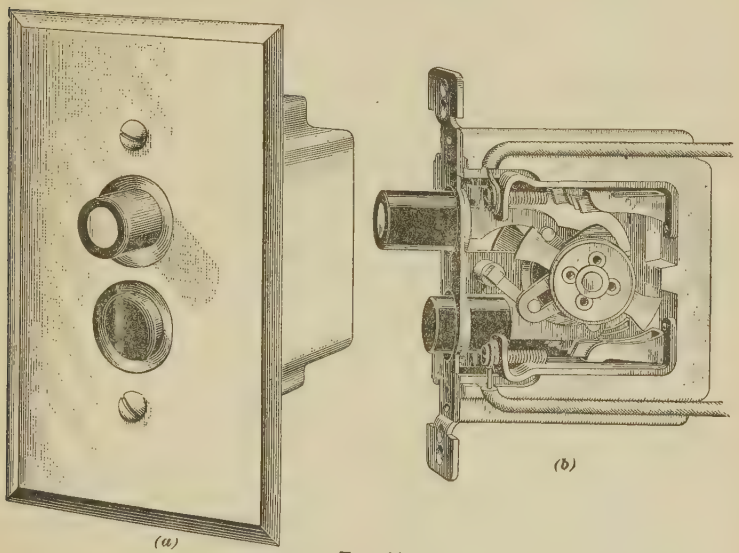


FIG. 36

mounted in a single box called a *gang box*. When two flush switches are mounted one above the other, they are said to be *in tandem*. Gang switches usually have a common faceplate. This is also true of tandem switches. It is the usual practice to use rotary snap switches for exposed knob-and-cleat wiring and molding work. The switches are mounted on porcelain sub-bases that keep the wires at least one-half inch from the surface wired over. In exposed-conduit work, the push-button or the toggle switch is as frequently used as the rotary type.

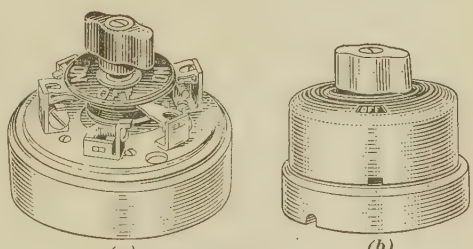


FIG. 37

Either type is mounted in boxes similar to those used for concealed work.

Of the three types, either push-button or toggle switches are preferred wherever they can be used, because they are usually more rugged and durable than rotary switches.

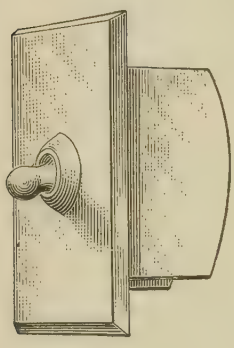


FIG. 38

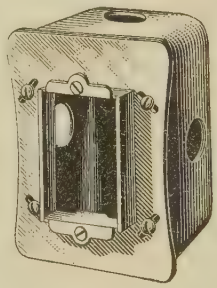


FIG. 39

99. Receptacles, or extension switches, types of which are shown in Fig. 40 (*a*) and (*b*) are used in connection with portable appliances such as reading lamps, small electric fans, and so forth. The portable appliance is wired through flexible cord to the insertion plug, or attachment plug, *a*, in (*a*), and connection to the building

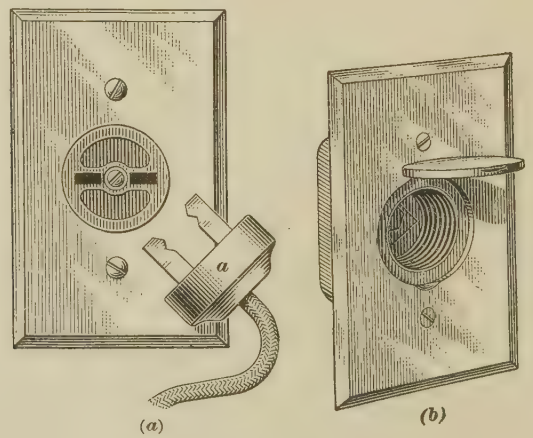


FIG. 40

wiring is made by pushing or screwing the plug into the receptacle, depending on the type used. The faceplates of some types of receptacles are provided with a small door that covers the receptacle when the plug is not in place, as shown in (*b*),

thus preventing the accumulation of dust in the contact openings.

100. The location of receptacles depends, of course, on the probable location of appliances to be served by them. The use of electric-heating devices is increasing so rapidly that it is always well to plan for an ample number of outlets, especially in the more costly residences. They can be located in convenient positions in walls or floors. If located in a floor or close to a floor, an approved floor box should be used for enclosing them.

A **pendent switch,** an example of which is shown in Fig. 41, is suspended by a flexible cord and used for the control of fixtures out of reach or inconveniently located.

A **pull switch** is any switch operated by means of a pull chain or cord, as shown in Fig. 42.

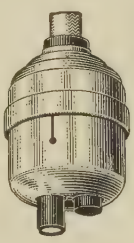


FIG. 41

FIG. 42

A **canopy switch** is one mounted in a fixture canopy. A **fixture switch** is one installed as part of a fixture. Various other names, such as *wall switch* and *ceiling switch,* each practically self-defining, are used in designating switches.

101. To make switches luminous, a composition containing a small amount of radium compound may be used. Radiolite is one trade-name for such a composition. The radiolite is embedded in the form of a small button in the faceplate. A small cylinder or ball treated with the compound may be attached to a pull chain.

SPECIAL SWITCHES AND CONTROL CIRCUITS

102. A **three-way switch,** or **three-point switch,** is one that can be used to connect a conductor with either of two other conductors. Two such switches can be connected as shown in Fig. 43, so that one or more lamps can be controlled by either switch, regardless of the position of the other switch. For

example, hall lamps can be controlled from either the upper or lower floor, or a garage lamp can be controlled from either the

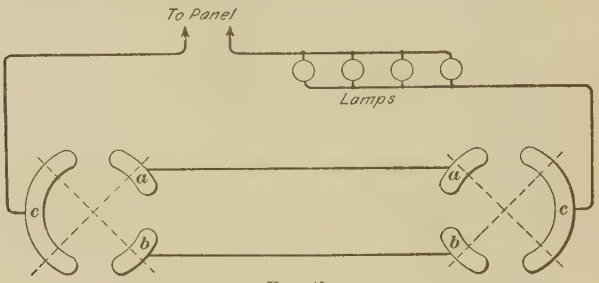


Fig. 43

house or the garage. In the illustration each switch may be closed in either of the two positions shown by dotted lines so that the circuit is complete either between contacts *a* and *c* or *b* and *c*. Thus, whatever may be the position of one of the switches, the other can be used to close or open the circuit through the lamps.

103. A **four-way,** or **four-point,** switch is one by which four wires can be connected in either of two combinations. In Fig. 44 are shown the connections of a combination of two three-point switches *A* and *C*, which may be on the first and third floors of a house, and a four-point switch *B*, which may be on

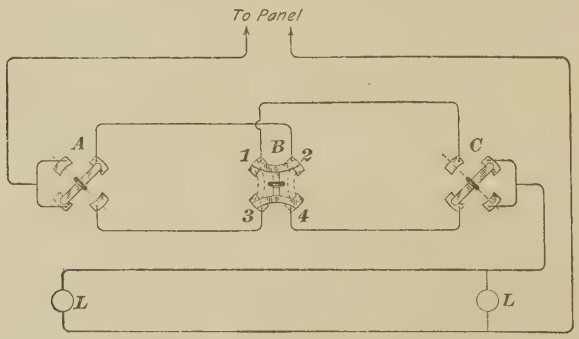


Fig 44

the second floor. Switch *B* is shown in the position to close the circuits between the points *1* and *2* and between the points *3*

and *4*, but it can be operated to connect the point *1* with the point *3* and the point *2* with the point *4*. The hall lamps *L* so wired can be operated from any one of the three floors.

104. A method of connecting three-point switches and a master switch for the control of groups of lamps, is shown in Fig. 45. Each group of lamps can be switched on or off by turning the contact of a switch to the points *a* or *c*, but any or all groups switched off at the three-point switches can be controlled by the master switch *b*. This arrangement is sometimes employed in residences to enable all the lights to be thrown on by a master switch in an emergency such as burglary or a fire. The master switch may be placed in the owner's bedroom or

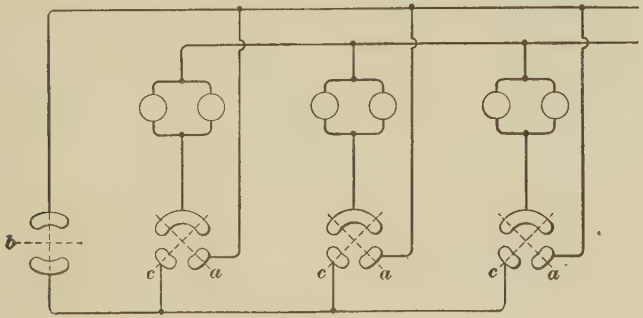


FIG. 45

any convenient place. It should be so installed that designing persons cannot tamper with it.

105. Two three-way switches are shown in Figure 46 (*a*), designed to control a lamp, a group of lamps, appliances, or fixtures from either of two points. Two three-way switches and one four-way switch, view (*b*), are designed to control a lamp or group of lamps, or fixtures, from any one of three points. Two-circuit or three-circuit switches are frequently used to control the lamps of an electrolier and are called *electrolier switches*. Views (*c*) and (*d*) show symbolic representations of the two types of these switches.

106. Switches for series-parallel combinations are useful for obtaining various degrees of heat in electric heating appli-

ances. They are frequently called *two-heat switches* or *three-heat switches,* as the case may be. A three-heat switch is one arranged to give a high-medium-low-off combination, or the reverse. A *remote-control* switch is a semiautomatic switch that can be opened or closed by means of an operating switch, or pilot switch. The remote-control switch is usually located near the apparatus to be operated and the pilot switch at a remote point more convenient of access. The remote-control system is of broad application. It is often used for the control of large motors in industrial buildings; also in public buildings and residences this system may be used to control a stationary vacuum-cleaner equipment. Where used for a cleaning system, the equipment is generally located in the basement of the building, and the pilot switches are located in various parts of the building where the cleaning devices are used. Lighting systems may also be controlled by pilot switches. A patrolman may shut off the lamps of a large store without entering the building. Lamps of an auditorium may be controlled from the stage or any part of the building, if so desired.

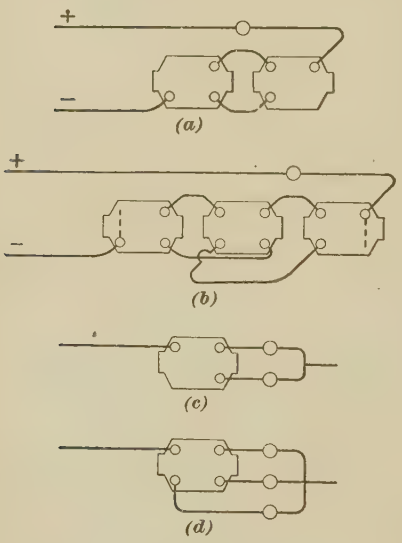
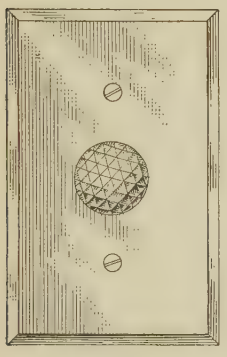


FIG. 46

107. There are many other kinds of automatic and semiautomatic switches, each kind adapted to a special purpose. One of these is the time switch which consists essentially of clockwork mechanically interconnected with a switch mechanism in such a manner as to open or close the circuit at a given time. Time switches are frequently used to control lamps of show windows and of electric signs.

108. Cellar lamps are frequently wired to be controlled by a switch located in a first-story room. A red pilot lamp, or indicator lamp, should be installed adjoining the switch that controls these cellar lamps to serve as a reminder that the cellar lamp has been left burning. Pilot lamps as shown in Fig. 47 are frequently used for this purpose. In (*a*) is shown the complete lamp, and in (*b*) the lamp with the faceplate removed.

109. An automatic door switch, as shown in Fig. 48, is used for automatically operating a lamp, or group of lamps,



(*a*) (*b*)

FIG. 47

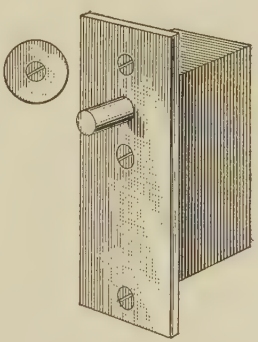


FIG. 48

upon the opening or the closing of a door. The switch is mortised into the door jamb and is operated by the action of a plunger that is pressed or released by the strike of the swinging door. Door switches find wide application in residences, where they are used in linen closets, clothes closets, pantries, cupboards, and toilets.

EXPOSED WIRING

WIRE-CARRYING DEVICES

110. **Knob insulators** for the support of wires are made in a variety of forms of which the solid knob, Fig. 49, is the most commonly used in interiors for carrying wires larger than No. 10. For smaller wires, split-knob insulators, examples of which are shown in Figs. 50 and 51, are used.

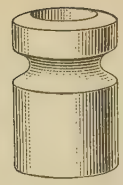


FIG. 49

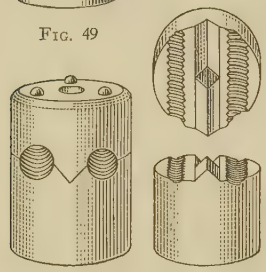


FIG. 50

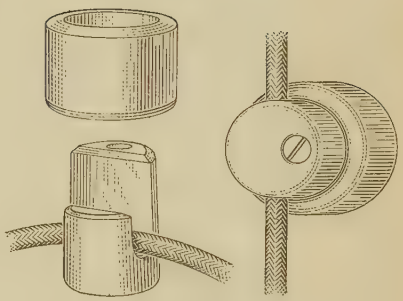


FIG. 51

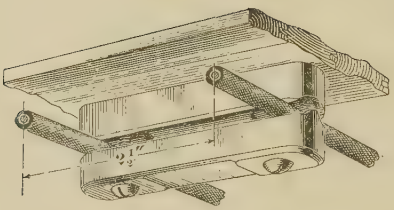


FIG. 52

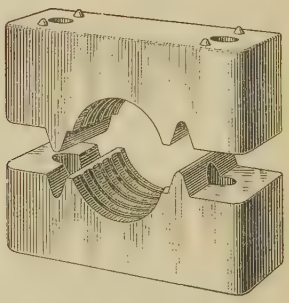


FIG. 53

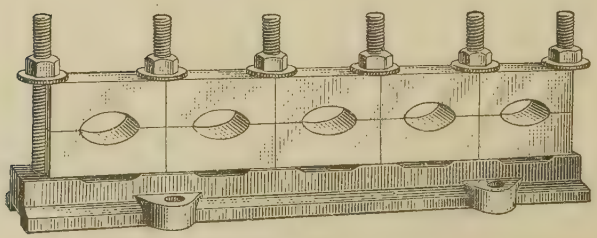


FIG. 54

Cleats are also made in a variety of styles, each adapted to a particular kind of service. A one-wire cleat accommodates only one wire; a two-wire cleat, Fig. 52, is grooved for two wires; a *three-wire cleat,* for three wires. The two- and three-wire cleats are made for wires as large as No. 2; for larger conductors a cleat for each wire is preferred. A typical cleat for large conductors is shown in Fig. 53. Where a number of conductors follow the same run, the usual practice is to clamp the cleats in iron frames, as in Fig. 54.

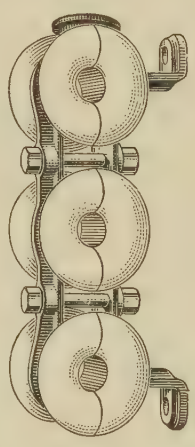


FIG. 55

Split bushings clamped in iron frames, as in Fig. 55, are also useful for carrying wires on walls and ceilings in exposed work.

Insulators for interior work are usually made of glazed porcelain, though glass is sometimes used.

EXPOSED WIRING INSTALLATION

111. Methods Used.—Methods of carrying exposed wires on wooden ceilings are shown in Fig. 56. Wires for mains not smaller than No. 8, if not likely to be disturbed, may be separated from each other about 6 inches and fastened on knobs attached to the timbers, as indicated at *a*. Smaller wires, or wires likely to be disturbed, as by the piling of boxes or the

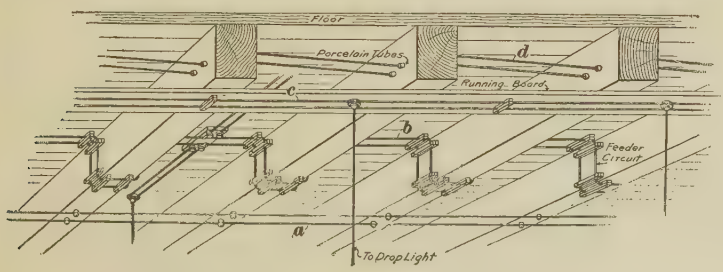


FIG. 56

moving of material, should be carried around the beams on knobs or cleats, as shown at *b*. Small wires crossing beams can

also be placed on running boards, as shown at *c*, or carried through the beams in unglazed porcelain tubes, as at *d*. When

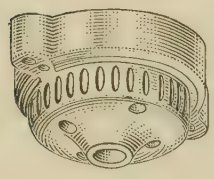


FIG. 57

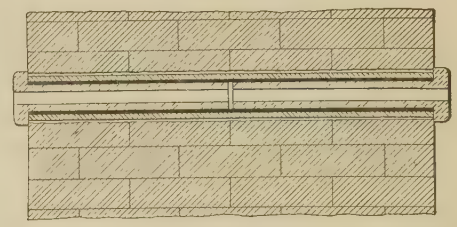


FIG. 58

the wires are run as in circuit *a*, guard strips are sometimes placed on each side to protect them from injury. Where drop lights—lamps suspended by cords—are to be hung, ceiling rosettes, as shown in Fig. 57, are used. In damp places the wires can be protected from dripping water by fastening the insulators in so-called wiring troughs.

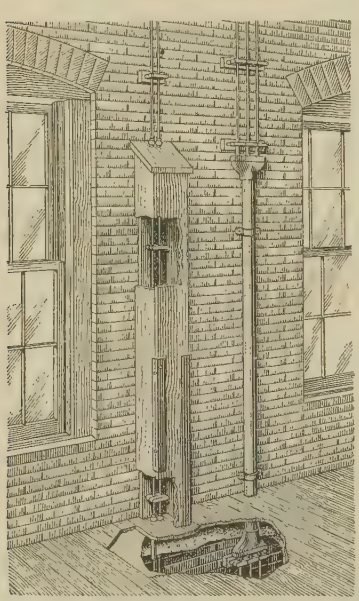


FIG. 59

112. A recommended method of running wires through thick walls is shown in Fig. 58, namely, in porcelain tubes that fit closely in an iron pipe. In thin walls or partitions, a single porcelain bushing can be used without the iron pipe. Where vertical runs of exposed wiring are carried through floors, the wires should be protected to a height of 7 feet from the floor by a method similar to either of those illustrated in Fig. 59.

113. For supporting racks carrying a number of heavy conductors, it is preferable to drill and tap the iron beams or columns and fasten the racks to them by means of machine bolts.

114. In any job of exposed wiring the most direct runs for the circuit should be selected. If possible, the crossing of pipes, especially steam pipes, should be avoided. Where wires themselves cross, the upper ones should be protected by porcelain tubes.

INSULATION REQUIREMENTS

115. Varieties of Insulation.—The insulating covering on conductors for open wiring on insulators need not be of the high grade required in other systems of wiring, because either the glass or porcelain insulators protect the conductors from each other and from the building, pipes, or other conducting material; the covering on the conductor is simply an additional safeguard. Rubber-insulated conductors are, therefore, unnecessary for this kind of wiring in dry places, and the general practice is to use conductors having slow-burning weather-proof insulation where there is apt to be any dampness; and slow-burning insulation in dry places, particularly where the temperatures are higher than normal. Both of these insulations are cheaper and more durable than rubber. Rubber insulation is required, however, for very damp places.

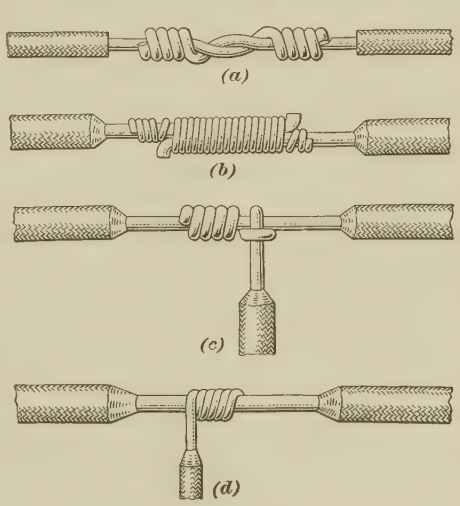


FIG. 60

116. Joints.—It is best wherever possible to avoid making joints in wires. When they must be made, however, the code requires that the joints be made mechanically and electrically secure. In making the joints the insulating material is first stripped from the portions to be joined and the wire scraped

until it is clean and bright and these portions twisted together. Fig. 60 (*a*) and (*b*) show splicing joints in continuous circuits and (*c*) and (*d*) show joints where one wire is connected to another to form a branch circuit. After the wires are twisted together and soldered, they are covered with insulating tape.

Joints in wires are not permitted in conduit systems of wiring except in outlet or junction boxes.

APPLICATIONS AND ADVANTAGES OF EXPOSED WIRING

117. Exposed wiring on insulators is especially adapted to mills, factories, and other buildings where appearance is not an object. This method of wiring is objectionable, however, in locations where the conductors may be damaged or deranged, or where there is no unobstructed space in which the conductors can be run without crossing pipes or other conductors.

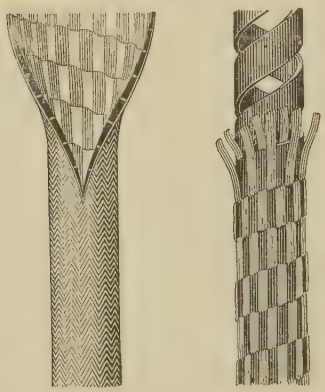


FIG. 61

CONCEALED KNOB-AND-TUBE WORK

118. Installation Methods. In concealed knob-and-tube work, the wires are carried on porcelain knobs in the spaces between beams and studs, and in porcelain tubes where they pass through timbers. Another accessory of this method of wiring is flexible tubing, or fiber tubing, a sample of one variety of which is illustrated in Fig. 61. The electrician generally speaks of fiber tubing as circular loom, or simply loom, to use a familiar trade-name.

119. Illustrations taken from typical installations of knob-and-tube work are given in Figs. 62, 63, and 64, showing the method of running the wires, the flexible tubing *a*, Fig. 62, and for supporting the outlet boxes *a*, Figs 63 and 64, and *b*, Fig. 62.

120. Convenient and quick methods of fastening switches and outlet boxes are shown in Fig. 65 (*a*) and (*b*). In (*a*) the

FIG. 62

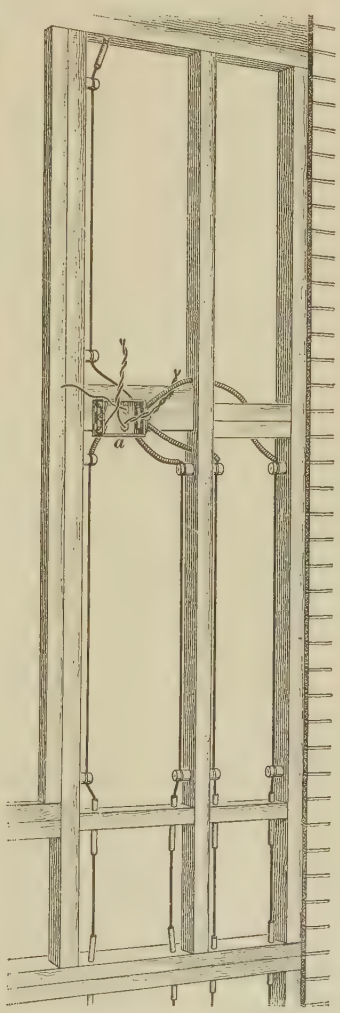


FIG. 63

outlet boxes *a* are secured to iron braces *b* that are fastened to the vertical studs *c* of the partition. At *a* in (*b*) are shown lath that are nailed to the studs *b* and to which plaster is applied.

The box shown at *c* is supported by braces *d* to which are fastened vertical bands *e* to hold the ends of the lath in place.

121. General Requirements.—According to the code, wires for knob-and-tube work must be covered with approved rubber insulation. The wires must be kept 5 inches apart, if possible; otherwise, metal conduit or armored cable must be used, except for voltages of 300 or less, when flexible tubing may be used, as at *a*, Fig. 62. It is advisable, where possible, to fasten the wires to separate beams or studs, as in Figs. 63 and 64, in order to keep them as far apart as practicable. The conductors must be supported at least every $4\frac{1}{2}$ feet, and if they are liable to be disturbed the supports must be placed closer together. Each wire that passes through a sill or header should have an additional porcelain tube above the one through the timber, to protect the wires from becoming embedded in plaster.

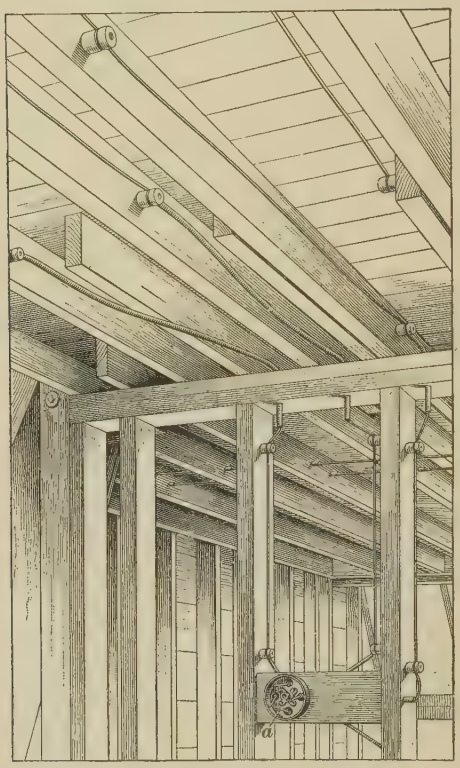
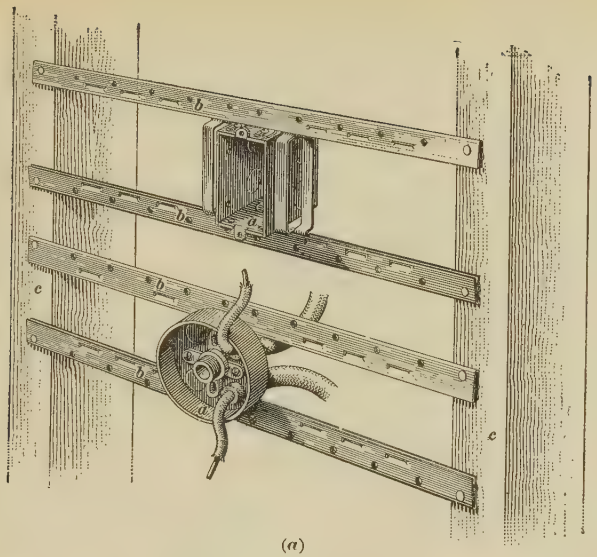
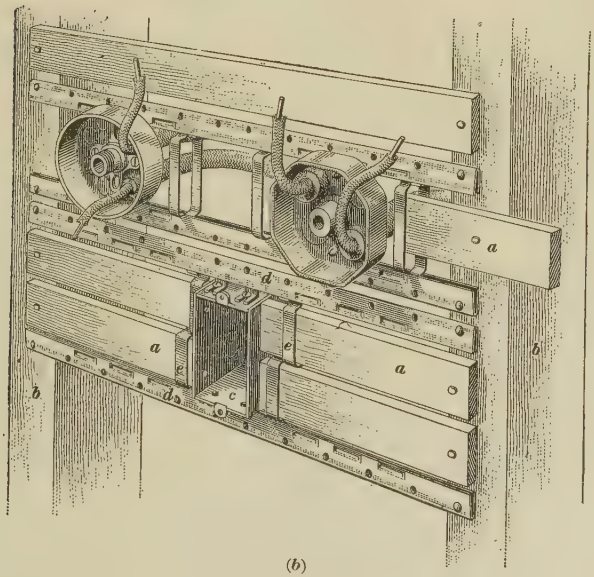


FIG. 64



(*a*)



(*b*)

FIG. 65

258—5

MOLDING WORK

WOODEN MOLDING

122. Description.—Wooden molding, Fig. 66, consists of a base *a*, with two or more grooves for holding the wires, and

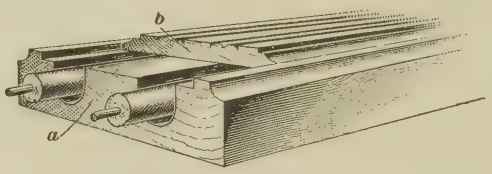


FIG. 66

capping *b* to give it a finished appearance. The base is first fastened to the surface to be wired; the wires are then put in place and held temporarily by small tacks or brads; finally the capping is nailed or screwed in place. Special porcelain fittings, called *taplets,* shown in Fig. 67, are used at places where the moldings intersect, to splice wires for junction leads. These fittings insulate and protect the joints in the wiring.

123. Requirements for Wooden-Molding Work.—In factories and stores, warehouses, and so forth, wooden molding on vertical runs must not approach a floor closer than 6 feet. Below this point and through the floor the circuits must be carried in pipe conduit with suitable outlets for connecting it to the molding. In places where the molding is less liable to mechanical injury, as in residences and office buildings, the molding can be brought down to the floor and protected at the bottom by means of an iron box called a *kick box.* The code rules do not per-

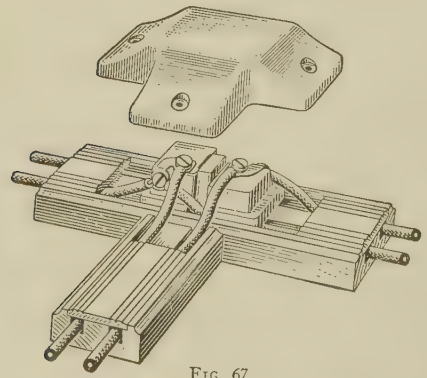


FIG. 67

mit wooden molding to be run through walls and floors; in such places porcelain tubes or metal conduits must be used to carry the wires.

124. Advantages and Disadvantages of Wooden Molding. Wiring in wooden molding, properly installed, presents a better appearance than any other form of exposed wiring. Moreover, molding can be run as cornices in halls and rooms, so that its appearance is scarcely noticeable. By fishing part of the wires through conduits and running the rest in molding, the expense of wiring completed buildings can be made less than if all the wires were in conduits, while the appearance is equally good. Wooden moldings are not, however, fireproof nor moisture proof. They are never used in damp places and are never concealed.

METAL MOLDING

125. Metal molding, Fig. 68 (*a*) and (*b*), has a trough-shaped base to carry the wires, and a capping to conceal and protect them. The base is drilled and countersunk at frequent intervals in order that it can be secured to the surface to be

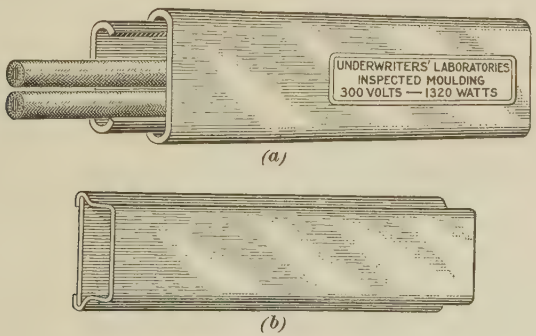


FIG. 68

wired. The heads of the screws that hold the base must be flush with the inner surface of the base. Special fittings are also made for this molding for intersecting points where splice wires occur for branch leads. Two of these are shown in Fig. 69 (*a*) and (*b*).

The obvious advantage of metal molding is that it is fireproof. Another advantage, as compared with wooden molding, is that it can be run through walls and partitions, provided a

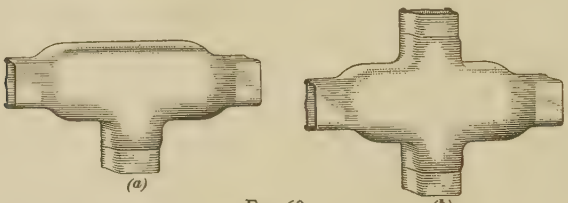


FIG. 69

continuous piece is used for the purpose, and provided there is no danger from mechanical injury or dampness. The metal molding also occupies less space than the wooden molding.

ELECTRIC WIRING
(PART 2)

Serial 1839B Edition 2

LIGHT AND POWER WIRING

CONDUIT WORK

RIGID CONDUIT

1. Iron-Pipe Conduits.—Although the most expensive, the best method of installing concealed electric wiring is by means of rigid iron-pipe conduits, as shown in Fig. 1. The conduit forms a raceway or channel between various outlets through which the wires are pulled or *fished* by means of a long, thin piece of steel called a *snake*.

2. Rigid iron pipe is the only type of conduit that should be considered for fireproof buildings, as this can be installed during the period of building construction, and the conductors pulled in after the plaster work is done. If any trouble occurs in any of the concealed circuits at any time after the building is completed, the wires can be withdrawn and the new ones inserted.

3. Iron-pipe conduit is practically gas pipe protected inside and outside by a zinc or black-enamel coating. The coating is applied to protect the pipe from deteriorating and to preserve the raceway. The coating also forms on the inside of the pipe a smooth surface that facilitates the pulling in of the wires. Some engineers prefer a conduit with enamel inside and zinc outside, in case the conduits are to be embedded in concrete.

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4. Conduits installed in places where the coating is likely to be acted upon by acids should preferably be enameled, as the action on coverings containing zinc destroys the coating. In order that the wires may be drawn through the conduit easily and without injury to the insulation, the inside edges of the

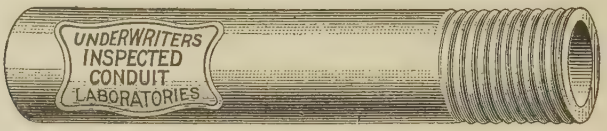


FIG. 1

ends of the pipe are reamed smooth before the protective coating is applied.

5. Rigid conduits are made in what is known to the trade as gas-pipe sizes from $\frac{1}{2}$ inch to 6 inches in diameter. The trade sizes up to 3 inches and the actual inside and outside diameters of these pipes are shown in Table I. The conduit is shipped from the factory in 10-foot lengths threaded on each end and provided with at least one coupling for each length. Any enamel on the threads should be removed by the electrician before the conduit is installed. When a piece of conduit is cut and threaded on the job, each cut should be reamed to remove the burr caused by the cutting. This is very important, as most of the trouble which develops in conduit is due to poor workmanship.

TABLE I

CROSS-SECTIONAL DIMENSIONS OF RIGID CONDUIT

Standard Pipe Size Inches	Inside Diameter Inches	Outside Diameter Inches
$\frac{1}{2}$	.622	.840
$\frac{3}{4}$	.824	1.050
1	1.049	1.315
$1\frac{1}{4}$	1.380	1.660
$1\frac{1}{2}$	1.610	1.900
2	2.067	2.375
$2\frac{1}{2}$	2.469	2.875
3	3.068	3.500

MISCELLANEOUS CONDUIT FITTINGS

6. Condulets.—Manufacturers produce approved fittings to meet nearly every conceivable requirement of conduit work, and market them under various trade names. Four of these fittings known as *condulets,* are shown in Fig. 2 (*a*) to (*d*), and the places in the conduit system where they are used are shown at *a* to *d*, Fig. 3.

7. Unilets, Taplets, and Multilets.—Similar fittings are made by other manufacturers to meet the same requirements, and are known as *unilets, taplets,* and *multilets.* These fittings are made in all standard pipe sizes up to 4 inches, and in shapes suited to all wiring purposes. Most of the special fittings are

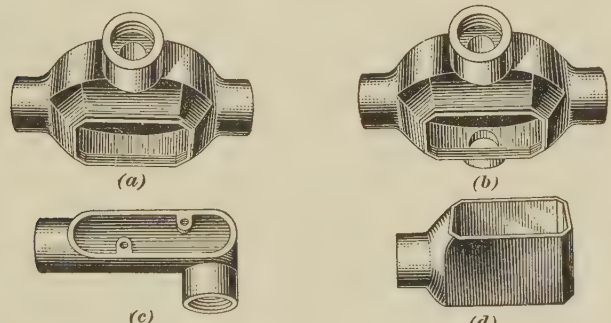


FIG. 2

designed to meet the requirements of exposed work, in which neatness is generally an important factor; but many of them are adapted to concealed work also. In exposed work, such fittings require no means of support other than that of the conduit to which they are screwed, but for concealed work the underwriters require additional means of support.

8. The ordinary gas-pipe **L**'s and **T**'s should never be used for conduit work, not only because such fittings are generally rough on the inside, but because they do not allow radii large enough to permit the wires to be inserted or withdrawn easily.

9. Outlet, or Knockout, Boxes.—An outlet box consists of a zinc-coated or black-enameled sheet-steel box with open-

ings through which conduits enter, and into which the wires are brought for connection to a fixture, switch, or other electrical device. The most usual forms of outlet boxes are shown in Fig. 4, the box in (*a*) being round, and the box in (*b*)

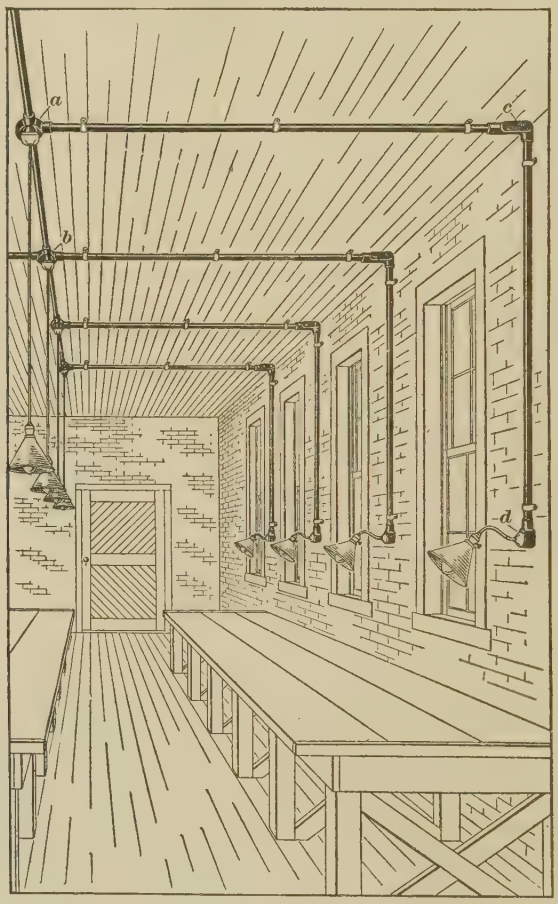


Fig. 3

square. The boxes are made of stamped steel, and are so constructed that openings to receive the conduits can be readily made at the back or at the sides by knocking out some of the circular pieces of metal with a hammer, hence the name *knock-*

out boxes. The lugs and setscrews *a* are for the attachment of suitable covers, the forms of which depend on the use to which the box is to be put. Holes *b* in the bottom provide means of securing the box to its support. Outlet boxes are installed at the same time as the conduit.

10. Two methods of fastening the ends of rigid conduit to an outlet box are shown in Fig. 5 (*a*). By the first method a coupling *a* is screwed to the threaded end of the conduit *b*, and a nipple *c* is thrust through the hole in the box from the inside and screwed into the coupling. The wall *d* of the box is held between the end of the coupling and the flange *e* of the nipple. This coupling is shown in (*c*).

11. By the second method shown in Fig. 5 (*a*) a locknut *f* is screwed on the end of the conduit *g*, which is then thrust through the hole in the wall of the box *d*, and a bushing *h* is screwed on so as to hold the box securely between the bushing and the locknut. The bushing is shown in (*d*) and the locknut in (*c*).

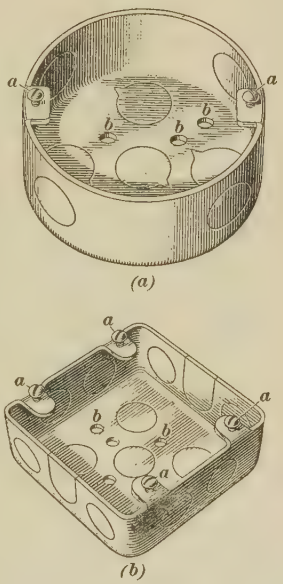


FIG. 4

12. Floor Boxes.—Floor boxes are special forms of outlet boxes designed for installation in a floor. They should be water-tight to prevent the entrance of mop water. Because of the difficulty of installing the regular floor box at the exact level required by the finished floor, the type of box shown in Fig. 6 is often used. The lower part of this box is installed with the conduit, and does not need to be perfectly level. The upper part of the box is installed later, and can be adjusted as shown to fit the lower part, and also to aline with the floor level. The joints between these two parts should be filled completely with cement. The lower part of this box is

made of thicker metal than are knockout boxes, and holes, to which plugs are fitted, are bored in the four sides. When it is

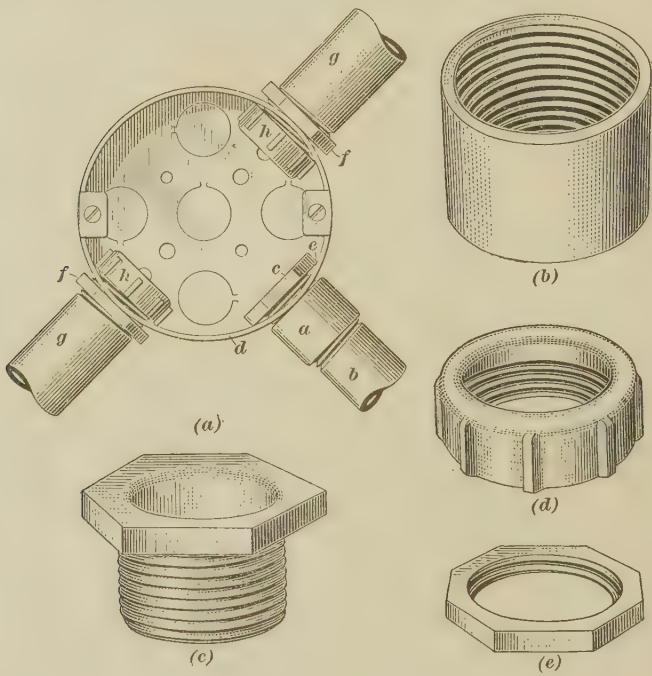


FIG. 5

desired to have a conduit enter these holes, the plugs are removed and the conduit attached to the box in the manner described for the ordinary knockout box.

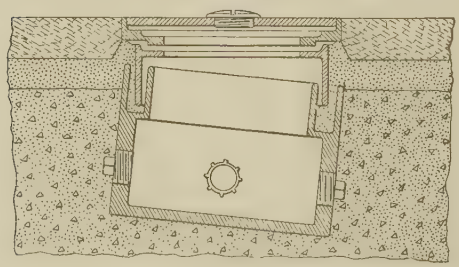


FIG. 6

13. Junction Boxes. A junction box, as the name implies, is used where two or more conduit lines intersect. The regular outlet box shown in Fig. 4 is generally used as a junction box when only a few conduit connections are required, while a large box, as shown at *a* in Fig. 7,

is used when there are many connections. Large boxes are frequently made to meet the exact requirements of the electrical installation. They must be provided with the same character of holes as the small box to receive the conduits, and the face or one side of the boxes must be provided with a door *b* or movable cover to allow of access to interior of the box for the installation or repair of the wires in the conduits.

Junction boxes are sometimes called *pull boxes* because the wires are pulled through the conduits from these places. On this account the installed boxes should be easily accessible. Junction boxes, instead of right-angle bends, are often installed in

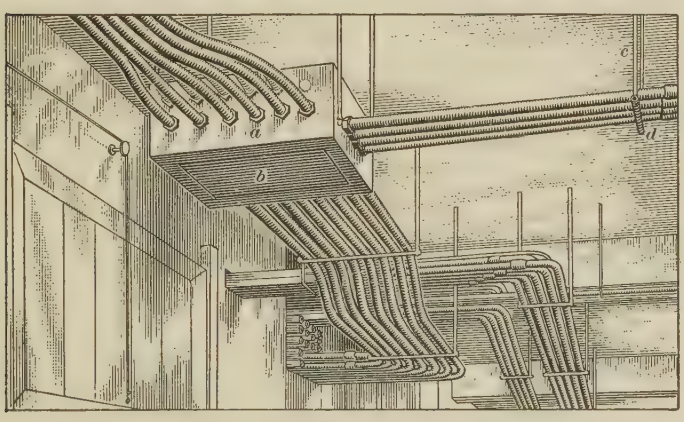


FIG. 7

the conduits. They are so used when the conduit run has a number of these bends and the pulling of the wires would be difficult on account of the excessive friction at these places.

14. Installing Horizontal Runs of Concealed Conduits. The manner of installing horizontal runs of concealed conduit in fireproof buildings depends on the type of the floor construction. If hollow tile is used for the floor, the conduits are not installed until the tile work has been completed and the wood centering removed. The conduits are then laid on the top of the tile and the ends of conduit bent to turn down and

connect with the outlet box on the ceiling below. In buildings having a hung ceiling the conduits are run on top of the channel iron which supports the ceiling.

For floor construction in a wooden frame building in which the wiring is concealed conduit or armored cable, a method of supporting a fixture from an outlet box is shown in Fig. 8.

15. If the floor construction is of reinforced concrete, the conduits should be placed on the wood centering erected to receive the concrete so that they will become embedded in the concrete. They should be installed at the proper time. If the steel reinforcement consists of bars, the conduit may be installed before the steel reinforcement. In most cases the conduit is placed above the bars, as in Fig. 9, and the boxes below. Junction boxes are shown at *a* and a light-outlet box at *b*. When expanded-metal type reinforcement is used, the conduit is usually placed above the reinforcement as in Fig. 10, which has openings to receive the outlet boxes *a* and *b*. The conduit should be wired to the reinforcement and the boxes nailed to the wood forms.

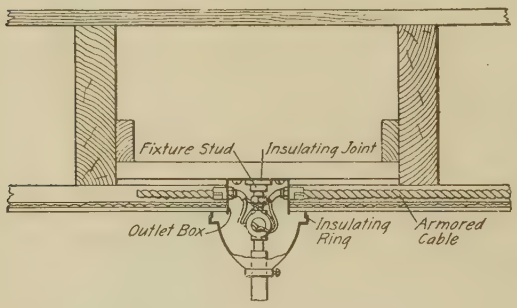


FIG. 8

16. In wooden frame buildings, conduits that run across the joists may be carried in grooves, so that the conduit is out of the way of the flooring, if laid on the under side. Conduits parallel to the joists are usually held in place by pipe straps as shown in Fig. 11.

17. Installing Vertical Runs of Concealed Conduits.—Single vertical runs, or *risers*, of concealed pipe conduits are

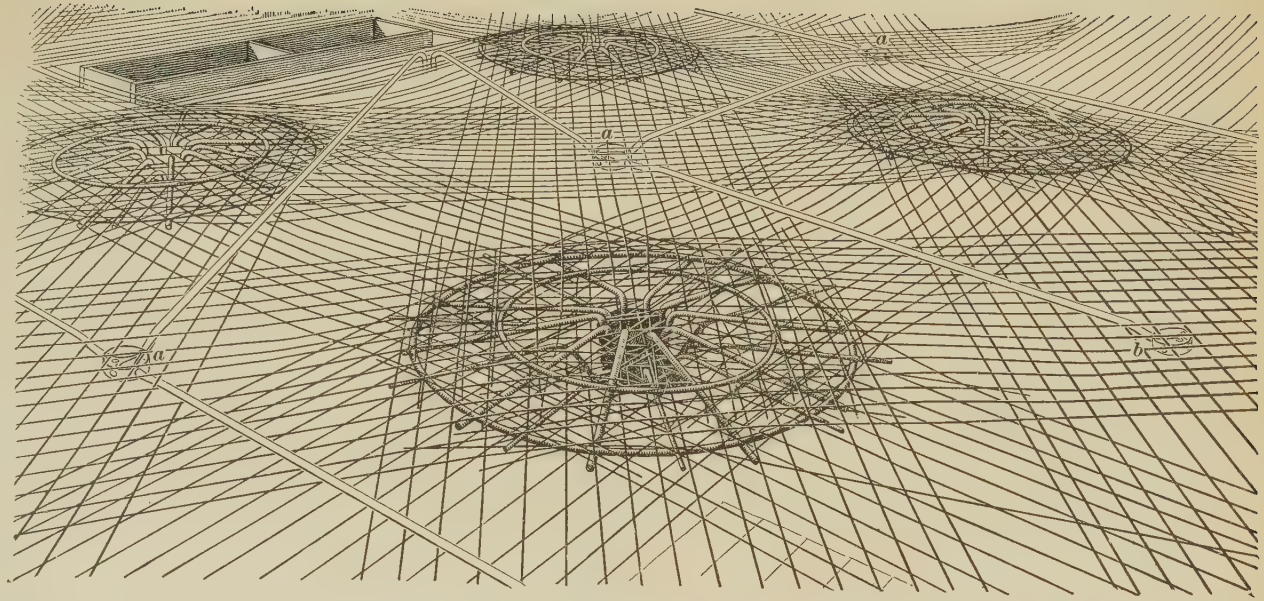


FIG. 9

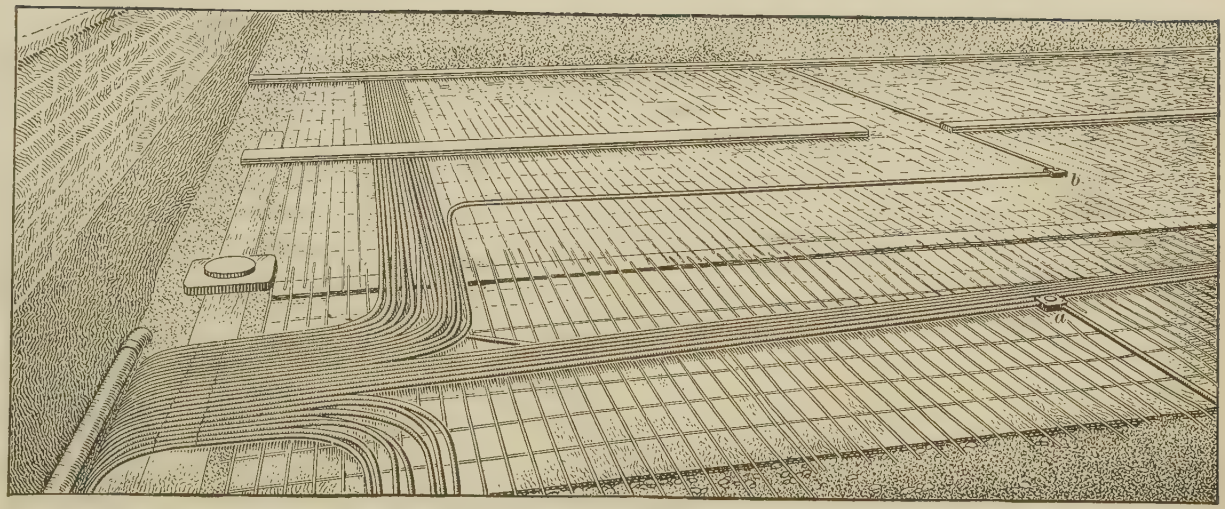


Fig. 10

generally installed sufficiently in advance of the masonry work that they can be built into the wall. When so installed, the boxes are usually attached to the conduits and both conduits and boxes are braced in such a manner that they will be held in a proper position during the erection of the wall. When the exact location desired for the box cannot be determined at this time, it is customary to terminate the conduits below the approximate location contemplated and a chase is left in the wall for the extension of conduits at a later time. This is very often required where the outlets are to be located in the center of a stile or panel of a wainscot.

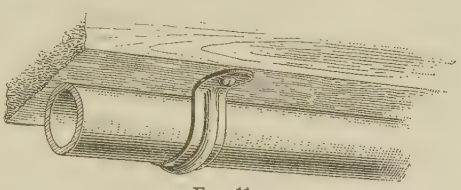


FIG. 11

18. Conduits that are run after the wall has been erected require the wall to be grooved or channeled to receive the pipe. The channel will require to be covered with metal lath to receive the plaster. Chases in the wall are usually provided for large conduits or for a number of small ones when they adjoin each other. A special wire shaft or pipe shaft is the best method

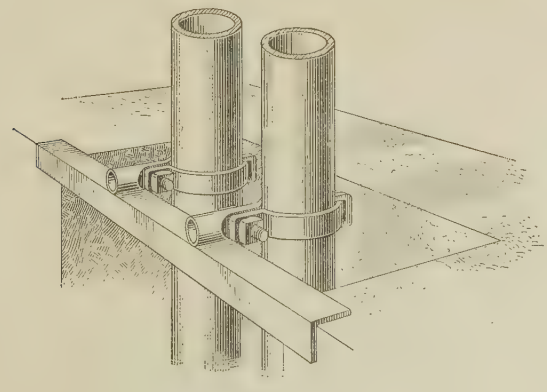


FIG. 12

for vertical runs of large conduits, although an elevator shaft may be used for this purpose if the location is suitable for the

work. Long vertical runs of conduits should have extra supports placed at each alternate story height to relieve the stress on the pipe couplings. These supports are usually obtained by the use of pipe clamps as shown in Fig. 12. The clamps are secured to the pipes and rest on steel angles previously built into the wall.

19. Installation Procedure.—The installation of the electric wiring system in a fireproof building is usually complex, and is of such a character that when once installed, it is hard to change. The architect should confer with an electrical engineer and determine upon all electrical matters before the structure is started, so that the plans of the structure may provide for all requirements of the equipment and its installation. The architect should know the size and location of all wire shafts, or pipe shafts, as they are frequently called, that will be required, also the size and location of all panel boards and chases in walls that are to be left for main conduits. If the size of these main conduits and the panel boards can be determined sufficiently early to permit the electrical contractor to have these parts of the equipment on the premises before the masonry walls are started, they may be set in desired positions and the walls built around them. This will insure better construction of the walls than to leave chases and recesses and fill in the unused spaces after the electric materials have been installed. If these conduits are built into the wall as suggested, they should terminate at the floor and ceiling with bends to which the horizontal lines can be connected when the conduits are to be continued to the various outlets.

20. General Requirements for Concealed-Conduit Work. The size of conduit to be used depends on the size and number of conductors to be drawn in, the length of the run and the number of bends in the run. The National Electrical Code contains a table covering conduit sizes for average conditions. The conduits must be continuous between outlets, junction boxes, etc., and must be secured thereto in such a manner as to make a good mechanical and electrical connection. At all points where conduits enter pull boxes, junction boxes, cut-out

cabinets, and similar accessories, approved fittings, called *bushings, plates,* or *nipples,* must be provided to protect the wires from injury as they are drawn. The conduit system must be effectively grounded.

21. The conduits must be installed first as a complete system before the conductors are drawn in. Conduit ends should never be left open for any length of time, as they are liable to become stopped with refuse, or water may enter them. The ends should always be kept closed by wooden plugs, corks, or gas caps until the wires are to be installed. Gas caps are preferred, as they can be screwed on to the ends of the pipe, and are not as likely to be removed as the wood plugs or the corks. All the wires for conduit work should be rubber-insulated and protected by a double braid, though the underwriters permit the single braid for single conductors in sizes smaller than No. 6 B. & S. gauge. When the entrance of moisture into a conduit is expected, lead-covered wire should be used.

22. All wires of the same part (feeder, main, or branch) of an alternating-current circuit must be installed in the same conduit. Conductors in vertical conduits must be supported within the conduit system at distances depending on the size of the conductors. Sometimes this necessitates the installation of steel boxes, similar to junction boxes, or distribution cabinets, but containing approved insulating clamps for the conductors.

EXPOSED PIPE-CONDUIT WORK

23. Supporting Conduit.—The clamp shown in Fig. 11 can be easily fastened to wood, but when laid against a terra-cotta wall toggle bolts are needed, as shown in Fig. 13. To support conduit against a brick wall, expansion bolts are used, as shown in Fig. 14. Where the conduit is carried on steel beams, special clamps, as shown in Fig. 15 (*a*) and (*b*), are employed. To provide for the support of exposed conduit (or any other kind of wiring) from concrete beams, cast-iron inserts, as shown in Fig. 16, which are recessed for machine bolts or studs, are placed in the forms before the concrete is

poured. A view of the insert is shown in (*a*), and a section in (*b*). The face of each insert is left exposed and the conduit clamp or fastening can be bolted to it.

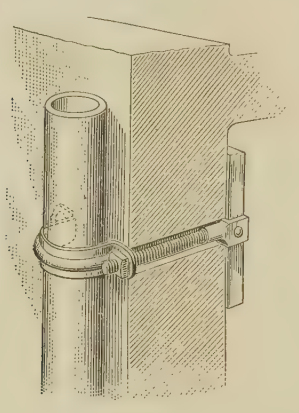


FIG. 13

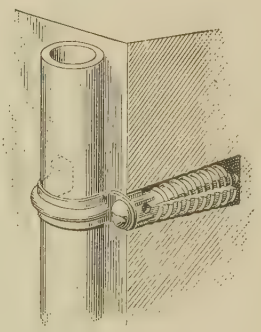


FIG. 14

To avoid drilling of masonry, pipe nipples of the required size can be placed in the proper locations in walls, floors, or

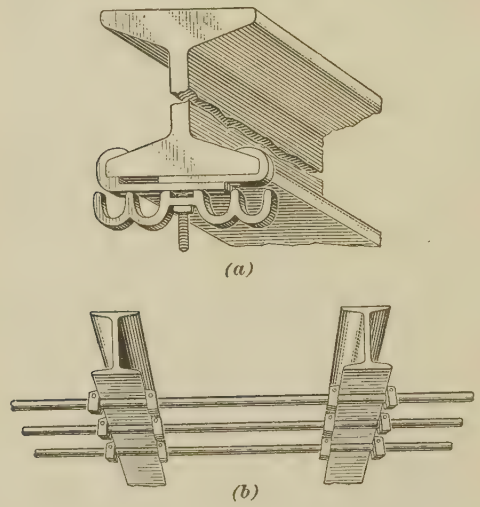


FIG. 15

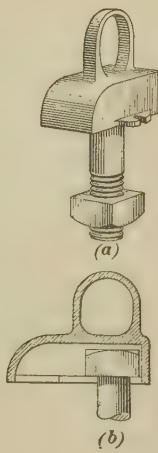


FIG. 16

partitions during their construction and the conduit later be coupled to the nipples. This use of nipples is especially desir-

able in concrete work in which the nipples can be held in the forms while the concrete is being poured. Until the coupling is being done, however, the nipples should be kept plugged. A method of supporting fairly heavy runs of conduit is shown in Fig. 7. Rods *c* support pipes *d*, on which the conduits rest.

24. The general requirements for concealed-conduit work apply to exposed work also. In work of this nature, where special fittings are not used, care should be taken to use right-angle bends of at least 6-inch radius, and otherwise to run the conduit so as to present a neat appearance. The conduits should be securely fastened at distances not exceeding 8 feet by clamps or supports, as previously described. Very frequently, circuit work in exposed conduits is preferable to concealed work, because of the probability of changing or shifting circuits at some future time. Exposed conduits may also be advisable in finished buildings where structural conditions or lack of space makes concealment difficult without materially disturbing the building, but metal molding is generally used for exposed work.

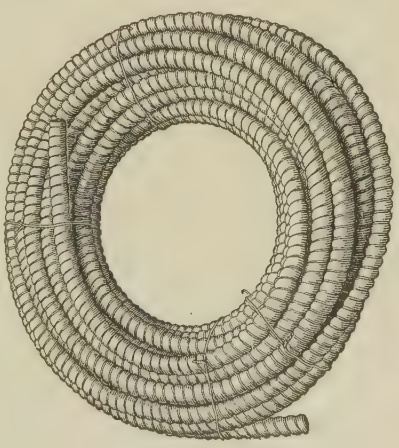


FIG. 17

FLEXIBLE-CONDUIT WORK

25. Flexible conduit work shown in Fig. 17 is made by winding two trough-shaped metal strips spirally on each other in such a manner that both the inside and the outside of the tube have a convex surface of a strip exposed. This conduit is fairly tight, though not altogether waterproof and is absolutely nail-proof. It is extremely strong and can be bent in any direction. The wireman usually calls it Greenfield conduit, giving a general application to the trade name of a prominent manufacturer.

26. An example of flexible-conduit installation is illustrated in Fig. 18. Here a combination gas-and-electric lighting system is to be used. Flexible conduits also are always completely placed before the wires are drawn in, and usually the wires are not inserted until after the building is plastered. This conduit also makes an excellent material to use when wiring buildings that are already completed, as small openings can be made in the floor, wall, or ceiling and the conduit fished

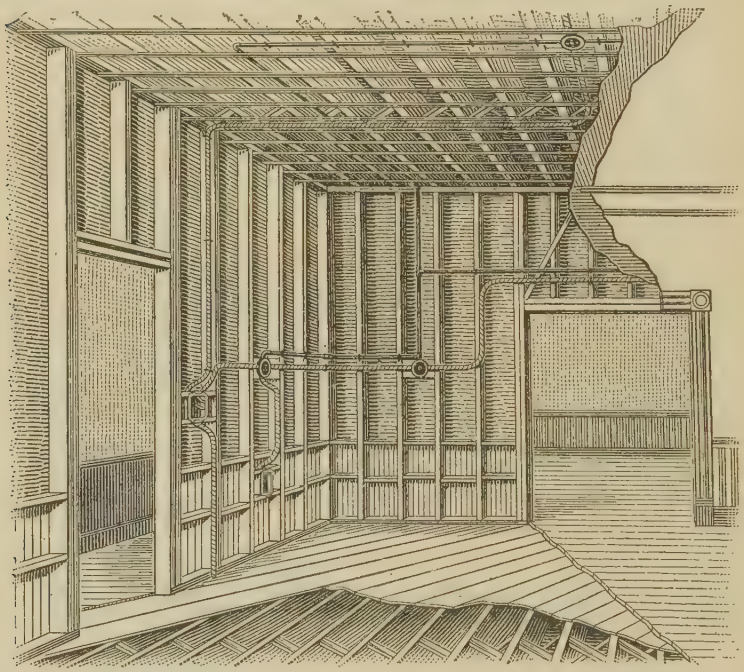


FIG. 18

from point to point. The material, weight, and form of flexible metal conduits are required to give as substantial protection as rigid conduits. It is essential, however, to fasten flexible conduit securely at frequent intervals in order to permit easy insertion of the wires.

The Code rules for pipe conduit apply to flexible conduit also. Wherever the conduit passes through slots in beams or studding, iron plates should be used to protect it from nails.

ARMORED CABLE

27. Armored cable, as shown in Fig. 19, is not, strictly speaking, a form of conduit, but it so nearly resembles flexible conduit in construction and installation that it is most conveniently described under conduit work. The electrician usually calls it BX cable, using the trade name of one of the earliest makes.

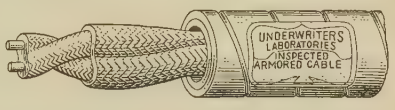


FIG. 19

28. Cable for use in damp places has a lead sheathing between the armor and the braided covering of the conductors, as shown at *a*, Fig. 20, and is practically as safe as conduit construction. The trade name for this type of cable is BXL, the letter L meaning lead-covered. Armored cable is recommended in preference to knob-and-tube work in completed frame buildings, both new and old, where there are a large number of circuits, as the cable can be installed with the least possible cutting of walls and floors.

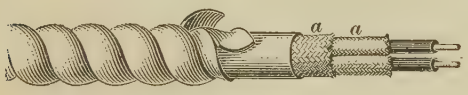


FIG. 20

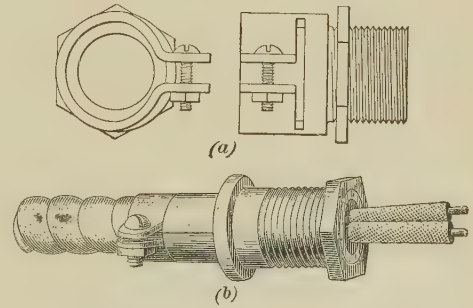


FIG. 21

29. The cable terminals must be securely fastened in outlet boxes, junction boxes, and cabinets, and the armor must be effectively grounded. Approved terminal fittings must be used, some of which are shown in Fig. 21. A malleable-iron

panel-box connector is shown in (*a*), a stamped-steel connector in (*b*), a 45-degree connector in (*c*), and a 90-degree connector in (*d*).

MISCELLANEOUS FITTINGS AND ACCESSORIES

LAMP SOCKETS AND RECEPTACLES

30. A **lamp socket** is a lamp-holding device designed to be fastened to a threaded pipe (as on fixtures) or hung on

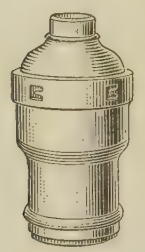


FIG. 22

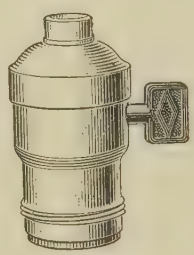


FIG. 23

FIG. 24

wires (as a pendant). A **lamp receptacle** is a lamp-holding device designed to be attached to a flat surface or within a box by a screw or clamping ring. **Sockets** are made

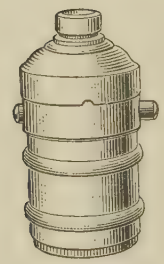


FIG. 25

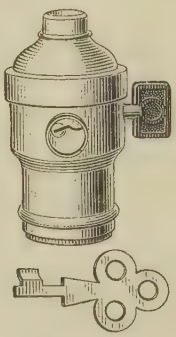


FIG. 26

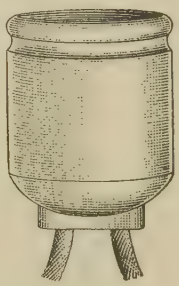


FIG. 27

with shells of metal (usually brass), porcelain, or molded composition. Metal-shell sockets can be obtained in any finish that can be applied to metal.

31. Several forms of metal lamp sockets are in common use. A keyless socket is shown in Fig. 22, a key socket in Fig. 23, a pull socket in Fig. 24, a push-button socket in Fig. 25, and a locking socket in Fig. 26. The keyless socket is the cheapest and is suitable wherever the current need not be controlled at the socket. The locking socket serves to lock the lamp so that no one without the key can remove it. Porcelain sockets are also available in each of these types, and should be used whenever they may be handled with wet hands, as in bathrooms, kitchens, and laundries. Weather-proof sockets, as shown in Fig. 27, are prescribed by the Code rules for damp places.

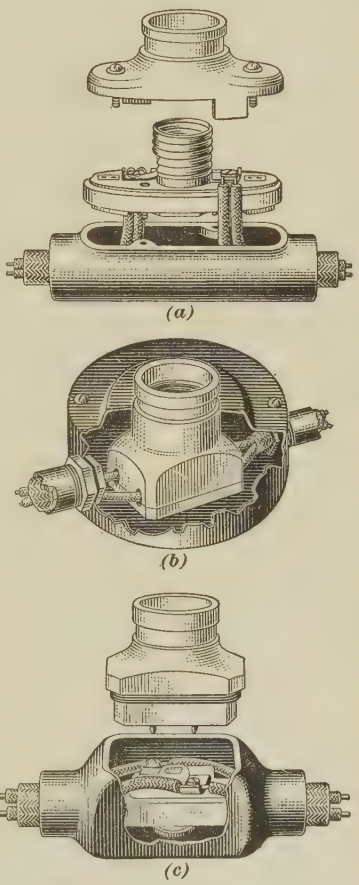


FIG. 28

32. **Receptacles** are usually made with shells of porcelain, or of brass with a porcelain base. In Fig. 28 (*a*) and (*c*) are shown examples adapted to special fittings for exposed conduit work. In (*b*) a special type of receptacle is shown mounted in an outlet box. The groove in the neck of each of these receptacles provides a means of attaching to it a lamp-shade holder. A useful receptacle, combining the functions of socket and canopy, and furnished with a pull switch, is shown in Fig. 29. This type is useful for overhead lighting in rooms with low ceilings and in corridors where few lamps are necessary. A keyless receptacle for exposed wiring is

illustrated in Fig. 30. As receptacles are not adapted to mounting on fixtures, their use is more limited than that of sockets. They find their chief applications in exposed work such as sign lighting, show-window lighting, and decorative lighting.

FIG. 29

33. In garages, oil refineries, chemical plants, and other places where inflammable vapors or gases may exist, a lamp and its socket or receptacle should be protected by a vapor-proof globe fitted air-tight in a suitable cap or in a reflector as in Fig. 31. If the wiring is exposed, the lamp and its accessories should be supported from a piece of rigid conduit enclosing approved rubber-covered wire. The wires should be soldered directly to the circuit and, if moisture is present, the upper end of the conduit should be sealed with insulating compound.

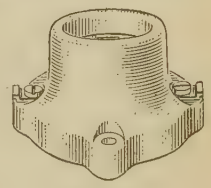


FIG. 30

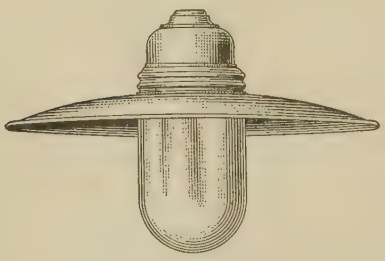


FIG. 31

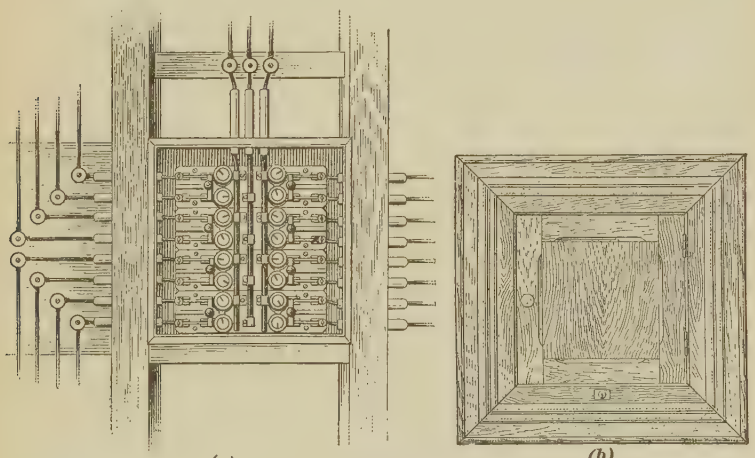
As regards size, lamp sockets and receptacles can be divided into three general classes: small, medium, and mogul. The small sockets are those used with candelabra and miniature lamps. The medium sockets are for the ordinary Mazda lamps. The mogul sockets are for street lamps and high-candlepower gas-filled lamps.

PANEL-BOARDS AND CABINETS

34. As previously mentioned, circuit work usually begins at a central place called a center of distribution, at which are installed switches for the control of the circuits and automatic cut-outs for the protection of the circuits. The switches and

cut-outs are assembled on what is variously called a distribution board, a cut-out panel, a tablet board, or a panel-board, and are enclosed in a cut-out box, a panel box, or a panel-board cabinet.

35. The term *cut-out box* is usually applied to boxes designed for surface mounting and accommodating only a few circuits, but it is also used frequently to designate the smaller and cheaper forms of boxes used in concealed work. A simple form of cut-out box for a small installation of concealed knob-and-tube work is shown in Fig. 32 (*a*). Porcelain blocks bear-



(*a*) (*b*)

FIG. 32

ing base fuses and switches are mounted in a wooden box lined with asbestos or metal. The mains and the branch circuits are led into the box through porcelain tubes. The finished box has a wooden door lined with fireproof insulating material, such as slate or asbestos board, and is finished on the outside as shown in (*b*).

36. A slate panel-board on which switches and cut-outs are mounted, is shown in Fig. 33. This board provides for ten branches from two-wire mains. The mains are connected to the lugs at the bottom of the board and clips are shown for

the main fuses that will connect the lugs with the vertical bus-bars, from which branch circuits, each identified by a number, are taken through switches and fuses. Panel-boards are made in many designs, depending on the service for which they are intended. In very large installations it is generally necessary to have panel-boards made to order.

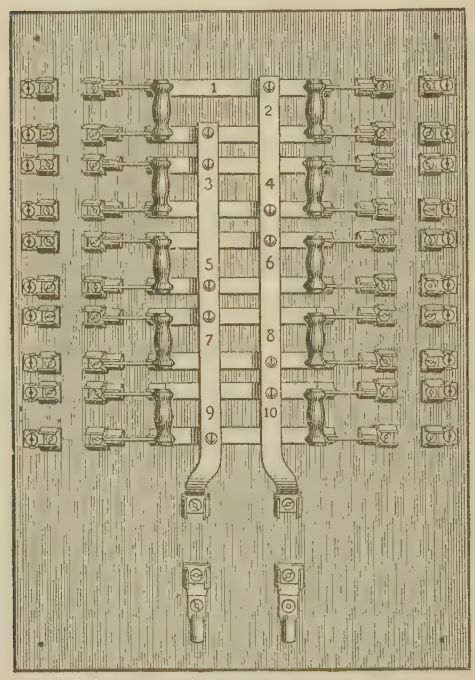


FIG. 33

37. In Fig. 34 is shown a panel-board mounted in its cabinet. The branch circuits are connected through knife switches *a* and enclosed fuses *b* to the bus-bars *c*, which receive current from mains led to the cabinet in the conduit *d*. The branch circuits are of twin wire carried in conduits *e*. Cartridge fuses *f* protect the mains. The lining *g* of the gutter, which serves as a wiring compartment, is of $\frac{1}{16}$-inch enameled iron. The barriers, or inner sides of the gutter, surrounding the panel-board, are of $\frac{1}{2}$-inch slate, of which material the board is also made. The complete cabinet has a door of steel which is sometimes lined with slate. This door swings on a removable frame, or trim, that covers the gutter.

38. In Fig. 35 (*a*) is shown a cut-out panel provided with specially designed push-button switches to eliminate trouble due to improper operation of knife switches. In (*b*) the doors and casings are shown in place. The doors are so arranged that the fuse compartment may be kept locked, while any one

can have access to the switches. The lugs, bus-bars, etc., of panel-boards should be of copper; the number of joints, or con-

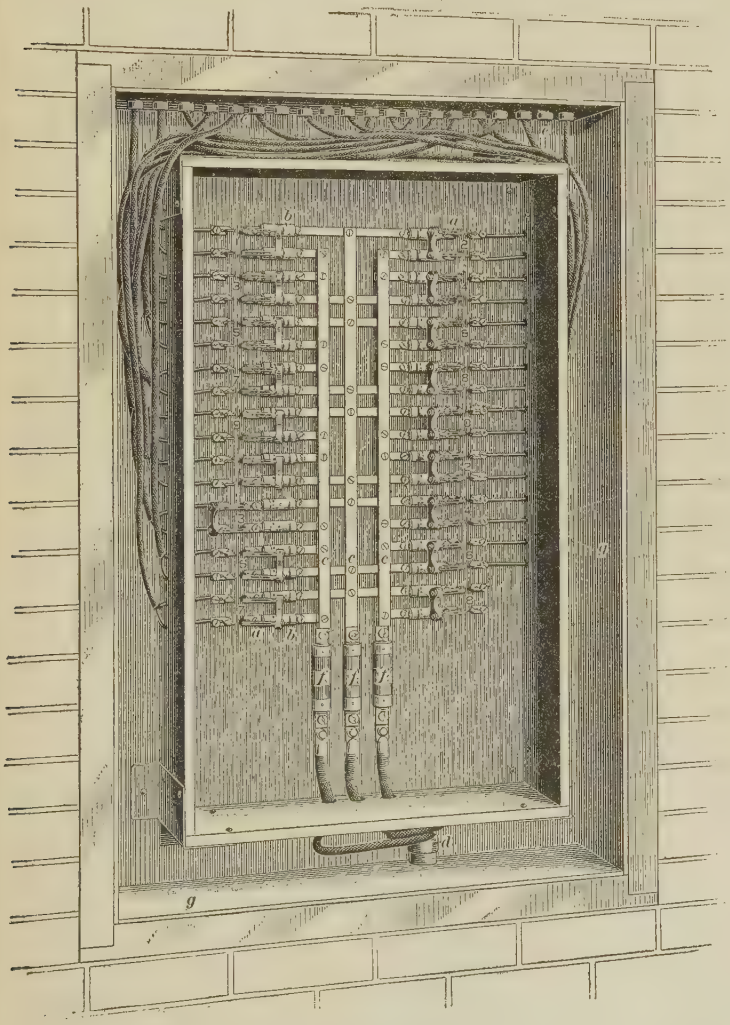


FIG. 34

nections, between the mains and branch-circuit wires should be reduced to a minimum, and the fuses, clips, and connectors should be of ample carrying capacity and mechanical strength.

39. Panel-boards having toggle, or tumbler, switches, as shown in Fig. 36, to control the main and branch circuits, are also extensively used. Wooden cabinets are permitted with knob-and-tube work, and with wooden molding, but they are not allowed with iron conduits, armored cable, or metal molding. When wooden cabinets are used they must be lined with

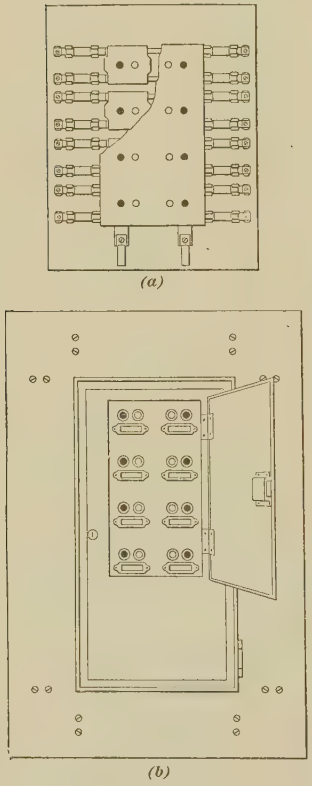


FIG. 35

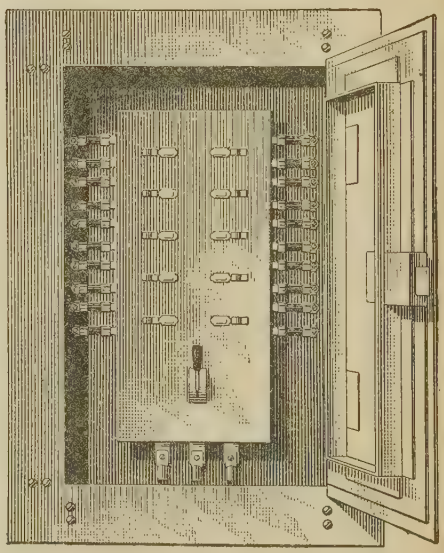


FIG. 36

approved non-combustible material and preferably covered on the outside also. It is good practice to secure to the inside lining of the cabinet door a frame in which can be placed a schedule, or directory, of the various branch circuits and location of the lamps that they supply. The schedule also gives the proper sizes of fuses for the feeders, mains, and branches.

FIXTURE SUPPORTS AND FIXTURES

40. Supports are installed to carry the light fixtures. For fixtures supplied only with electric current a fixture stem or stud of the type shown in Fig. 37 is generally used in both wall and ceiling outlet boxes, to which the fixture may be connected. Where heavy ceiling fixtures are contemplated, however, a special hanger, called the *Hickey fixture hanger,* as shown in Fig. 38, is generally installed. Supports made of gas pipe are sometimes used for this same purpose and are formed and installed as shown in Fig. 39 (*a*) and (*b*). Fixtures to be supplied with gas are usually supported by the gas-pipe fittings.

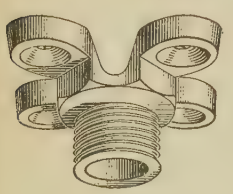


FIG. 37

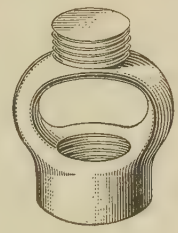


FIG. 38

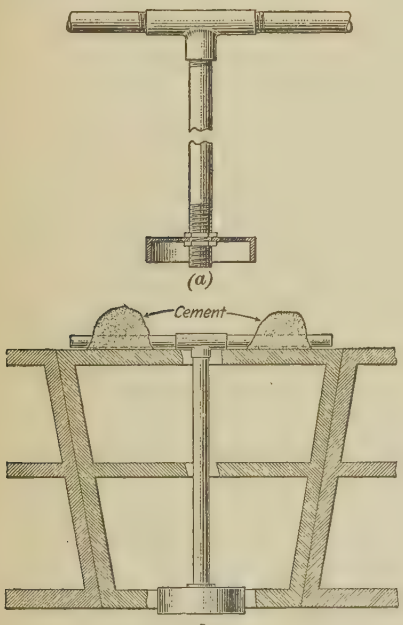


FIG. 39

41. Insulating joints should be used when fixtures are supported at outlets in metal-conduit, armored-cable, or metal-molding systems; fixtures should also be insulated from gas piping or any grounded metal work, from metal walls or ceilings, from plaster walls or ceilings containing metal lath, and from walls or ceilings in fireproof buildings. There are many different kinds of insulating joints for electric fixtures, one form of which is shown in Fig. 40.

Fixtures installed on circuits above 150 volts to ground, and all fixtures used with conduit, armored cable or metal raceways, should be grounded. Fixtures for open wiring, knob-and-tube work, non-metallic sheathed cable, metal-lath ceilings or side walls, need not be grounded or even insulated. Fixtures are considered as grounded when mechanically connected to metal conduit, tubing, armored cable, the ground wire of non-metallic sheathed cable, etc., or to a grounding wire not smaller than No. 14, or to gas piping which is properly grounded. No fixture conductor shall be smaller than No. 18 wire.

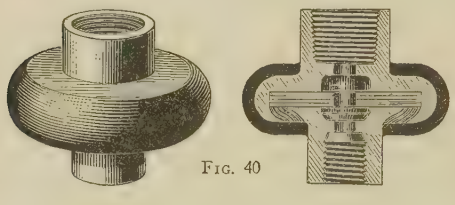


FIG. 40

TRANSFORMERS, SERVICE ENTRANCES, SWITCHBOARDS, AND METERS

TRANSFORMERS

42. If the current is alternating, it is usually transmitted on the line wires from the central station at a voltage too high for the wiring in the interior of a building, and transformers must be installed near the building to reduce the voltage. The company from which the power is purchased generally supplies and installs the transformers. The preferred location for transformers is outside the building for which the power is purchased, possibly on a nearby pole or in a small isolated building for transformers only, or possibly in an outdoor enclosure. The transformer may also be fastened to the outer wall of the building, or installed in an outside vault, as shown in Fig. 41. The rules and regulations of the Code govern the manner of constructing these vaults, and should be referred to before proceeding with any of this work.

Transformers in buildings may be installed only with special permission of inspection bureaus. They must be located as

closely as possible to the point at which the primary wires enter the building, and must be placed in a fireproof room used for no other purpose. The transformer room, or enclosure, must be practically air-tight, except that it must be thoroughly venti-

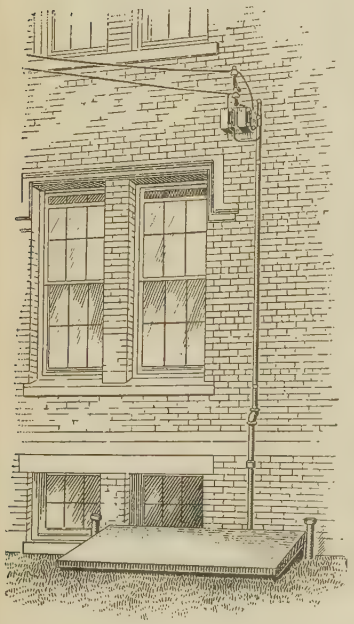


FIG. 41

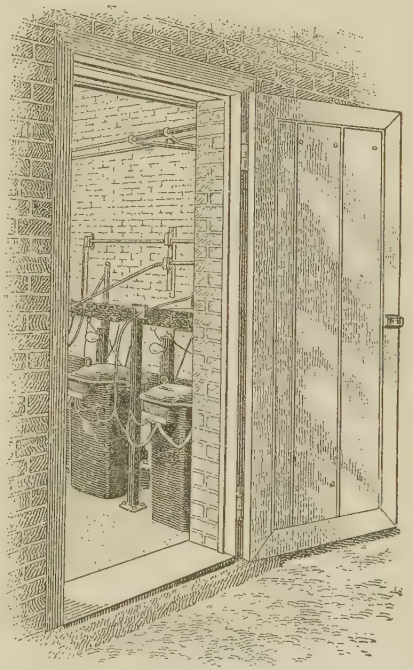


FIG. 42

lated to the outside air, preferably through a chimney or flue, and the floor provided with a cesspool and drain. The equipment required for the entrance to a transformer room is shown in Fig. 42.

SERVICE ENTRANCES

43. The location of a service entrance to the building depends on the location of the light-and-power company's mains. The architect should, therefore, confer with a representative of the power company relative to these mains before he determines upon the location of the service entrance or the

transformer room, and he should provide for their installation in his electrical specification. This will permit the architect to make provision for openings in the foundation walls, through which the service lines may be brought after the wall has been completed.

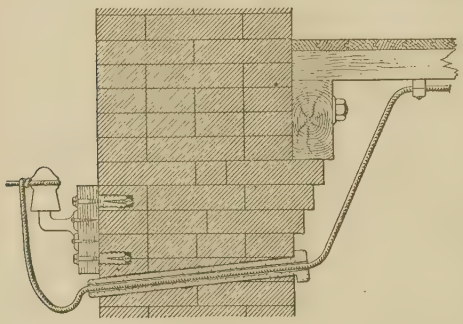


FIG. 43

44. Examples of service entrances from overhead mains are shown in Figs. 43 to 45. In the first installation the wires enter the building through a porcelain tube inclined toward the outside of the wall in order to prevent the entrance of water. In the second the wires enter through a pipe conduit by way of a special service head. In the third the leads enter the basement of a residence in a conduit provided with a special service head *a* and a special elbow *b*.

45. When an owner objects to the carrying of overhead wires to his building, and he is willing to meet the extra expense, arrangements can generally be made with the lighting company to bring the service leads underground from a nearby pole. The installation of the underground cable can be made by the company or by the electrical contractor working under the company's direction; in either case the final work of connecting the wires to the overhead mains will be done by the company.

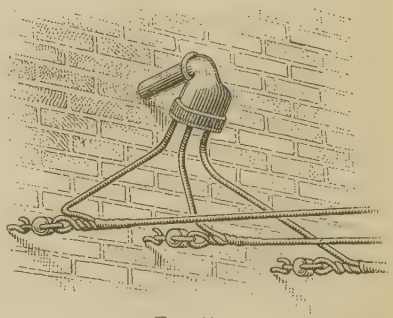


FIG. 44

46. Underground distribution mains are usually encountered in the down-town, or business, districts of the larger cities. Access to the underground system is obtained by means

of manholes located at street intersections and at necessary intermediate points. In the manholes are installed junction boxes by means of which the customers' service leads are connected to the company's mains. Underground service leads, therefore, necessarily begin at a manhole, and enter the building through the basement wall. The switchboard

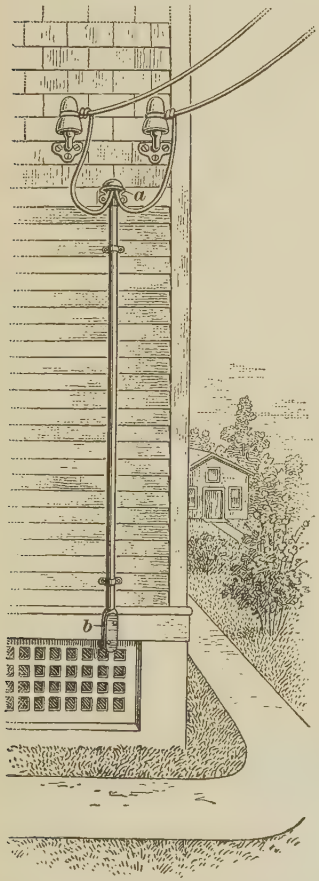


FIG. 45

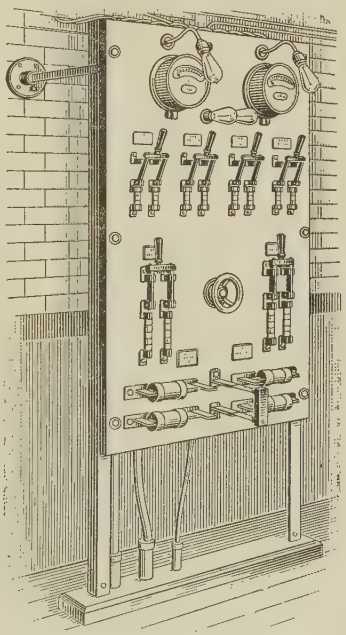


FIG. 46

and the wiring shaft should be located close to the service entrance to simplify the wiring system, and to reduce the cost of the installation.

SWITCHBOARDS

47. Typical switchboard construction consists of slate or marble slabs, or panels, mounted on vertical frames of pipe or angle iron. A switchboard may consist of one panel, as shown

in Fig. 46, or it may have a series of panels as shown in Fig. 47. The number of panels depends on the size and nature of the distributing system to be controlled at the board. The front of the board usually bears only the equipment such as circuit-breakers, switches, fuses, instruments, etc., that must be easily accessible for operating the system, and this equipment should be neatly arranged and installed. The connection of the wires to the board should be made from the back, and ample space should be allowed at the rear of the board for this purpose.

48. The design of the switchboard and its location in the building should be left to the electrical engineer; the architect

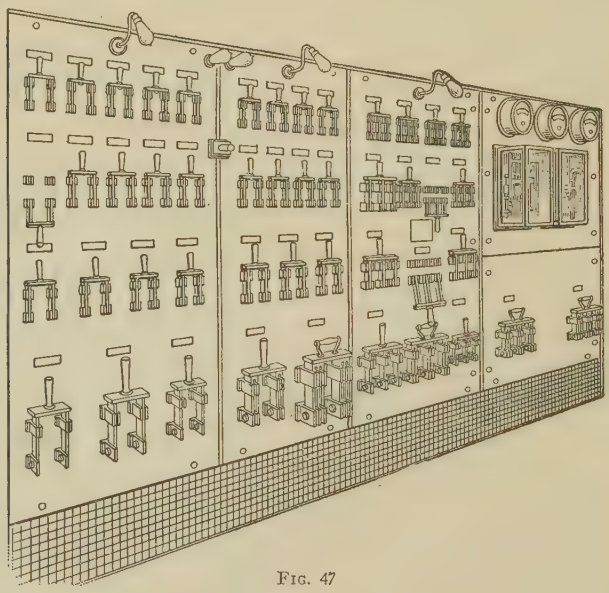


FIG. 47

should, however, know that switchboards for general use are arranged in three divisions, lighting panels, power or motor panels, and either generator panels or service panels. Generator panels are required when the equipment comprises an isolated generating plant; and service panels, when energy is received from an outside source. Either of these panels serves to collect the current from the source and pass it to the

other panels which, collectively, are called *distributing panels.* Switchboards are made in such a variety of sizes and kinds that for ordinary requirements they may be selected from manufacturers' catalogs, combining boards of the various types as required. When a switchboard of special design is required, it is necessary to consult the manufacturer and explain in detail what is required.

METERS

49. The watt-hour meters necessary to register the quantity of electricity used are generally provided and installed by the central station company. The electrical contractor arranges his wiring and provides and erects the meter boards according to the requirements of the company. When the meters are to be located on switchboards, it is necessary to obtain templets of such meters from the electric company, and send them to the manufacturer so that he may design and drill the switchboards to accommodate the meters. The meters remain the property of the central-station company. In office buildings, meters should be located in meter closets or other central places that are accessible. In residences and apartments they should be located in the basement or service part of the building where they may be read without annoyance to the owner or tenant. The last rule applies to office buildings and apartment houses in which the tenants pay their own electricity bills, or in which it is desirable for any reason to keep separate the amounts of electricity used.

HEAT, POWER, AND SPECIAL LIGHTING

ELECTRIC HEATING

50. Heat from electrical energy can be used for any purpose, but the great drawback to its use for general heating purposes is its expense. In residences electric heat gives the greatest service in portable appliances. A list of these appliances that are adapted to household use is given in Table II. When the architect is preparing plans for the electric work, he should

confer with the owner of the building, to learn what devices are contemplated, and also what devices might be desired at some future time, so that circuits and switches may be provided and installed for both immediate and future requirements.

TABLE II

HOUSEHOLD ELECTRIC HEATING DEVICES

Appliances	Watts
Broilers, Three-heat	300 to 1,200
Chafing dishes, Three-heat	200 to 500
Cigar lighter	75
Coffee percolators	100 to 500
Corn poppers	300
Curling-iron heaters	60
Double boilers, Small	100 to 500
Flatirons, 3-pound to 9-pound	275 to 610
Foot warmers	50 to 400
Frying kettles, 8-inch	825
Griddles	330 to 1,500
Heating pads	50
Kitchenettes (average)	1,500
Milk warmers	450
Ornamental stoves	250 to 500
Ovens	1,200 to 1,500
Plate warmers	300
Radiators	700 to 6,000
Ranges (depending on capacity)	1,000 to 7,200
Shaving mugs	150
Stoves (depending on size)	50 to 1,500
Toasters (depending on size)	330 to 1,500
Urns, 1 to 5 gallons	110 to 1,700
Waffle irons (for 3 waffles)	1,150

51. Flatirons, percolators, and ranges are extensively used, and special provision should be made for these appliances. Mangles should also have a separate circuit when the rolls are

heated by electricity. Where several irons are to be used simultaneously, it is necessary to provide a special circuit.

52. The use of electric energy for the continuous heating of rooms is usually confined to localities where electricity can be generated very cheaply, or to places where cost is the relatively unimportant item. Small electric heaters are used as auxiliaries to hot-air, hot-water, or steam systems. They are employed temporarily in places such as bathrooms or bedrooms. The heaters most generally used for this purpose are of the portable type.

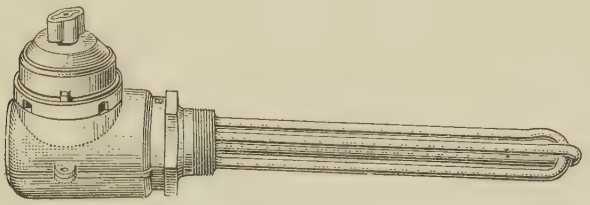


FIG. 48

53. The heating of water electrically can be accomplished by either of two general methods, the instantaneous system or the storage system. With the instantaneous system the heater current is turned on simultaneously with the opening of the faucet, and the water is heated to the required temperature as fast as drawn. The storage system employs a tank wherein the water can be either heated or stored, or both. An automatic water heater of the immersion type is shown in Fig. 48.

54. The wiring for electric heating depends, of course, on the nature and capacity of the equipment. The Code does not require a separate circuit for a device taking less than 660 watts, but when a heater is connected to a lighting circuit, the total load on the circuit must not exceed 660 watts. Practically interpreted, it means that a separate heating circuit must be run for every heating appliance of over 500 watts. Each heater or group of heaters of more than 660 watts capacity must be protected by a cut-out and controlled by a switch or a plug

located within sight of the heater, and plainly indicating whether the current is on or off. These rules determine the number of heating circuits, and also the location of the heater switch.

55. The rule regarding heater switches sometimes requires the installation of a pilot lamp to indicate whether the heating switch is open or closed. An ordinary incandescent lamp properly connected to a knife switch fulfils the requirement, but a neater job is obtained by the use of a push-button switch of the proper rating and a small lamp mounted behind a red bull's-eye in a flush wall plate. For extension circuits, manufacturers make outlet assemblies such as shown in Fig. 49, comprising a pilot light *a*, push-button switch *b*, and extension-plug receptacle *c*. No other safety precautions are necessary for heating devices, except that special heater cord, as prescribed by the underwriters, should be used for portable appliances.

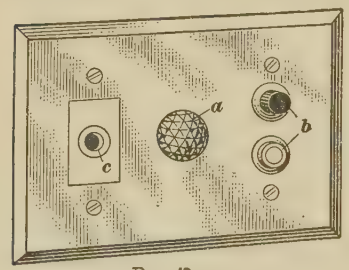


FIG. 49

56. In most cities the central-station rate for heating is lower than that for lighting, so that separate meters and wiring systems are necessary for the two. The circuits for heating current are generally led to comparatively few points in the building where heating appliances are to be used. The double system of wiring and metering is avoided in some localities where the central-station rate is sharply reduced after the consumption passes a certain quantity each period. This predetermined quantity is the estimated amount of energy which will be used for lighting.

ELECTRIC MOTORS

57. The selection of motors for the various requirements of a building should be referred to the electrical engineer, also the selection of the devices that form the motor auxiliaries and the wiring installed to conform with the special requirements of the motor and the device selected. Some makes of washers take a very large starting current, so that a circuit with a capacity of 20 amperes or more should be provided.

58. For general information, Table III is given to show the various application of motors and also as a reminder in

TABLE III

MOTOR-APPLICATION REMINDER

Elevators	Dish washers	
Escalators	Portable tools	
Dumb waiter	General utility	
Sidewalk lifts	Ice-cream freezers	
Freight hoist	Dough mixers	Hotels and restaurants
Blowers	Meat choppers	
Exhaust fans	Knife cleaners	
Ventilating fans	Pitcher cleaners	
Portable fans	Grinders	
Fire pump	Sewing machines	
House pump	Addressing machines (offices)	
Air (pressure) pump	Paper cutters (offices)	
Vacuum pump (cleaner)	Printing machines (offices)	
Mechanical refrigerator	Dental machines	
Laundry machinery	Electric sweepers	
Package conveyers	Washers	
Workshop (residences)	Mangles	

making the plans for the electrical equipment. Some of the motor auxiliaries that are required are a starting device, a main knife-blade switch, a circuit-breaker, or fuse, and a starting-device panel-board. The starting devices may be hand-operated, semiautomatic, or automatic. The semiautomatic

control is similar in action to the remote control, in that it is operated by means of a pilot switch placed at a distant point. The automatic control is similar to the semiautomatic except that the operating current is controlled by a mechanical or electro-mechanical switch which may be controlled by air pressure, by water pressure, by the rise and fall of a float, etc. The switches, circuit-breakers, fuses, and panel-boards are of the same character previously described for regular electric equipments.

59. Small portable motors for household use range in size from $\frac{1}{20}$ to $\frac{1}{4}$ horsepower. These motors can be operated from a lamp socket provided the combined motor load and lamp load on the circuit does not exceed 660 watts. But, for the sake of convenience, it is well to provide extension-plug receptacles at desirable points in a building for this purpose. These receptacles should be on branches separate from the lamp circuits.

ELECTRIC SIGNS AND DISPLAY LIGHTING

60. Electric signs or devices for the illumination of the exterior walls of a building are rarely included in the original plans of the building. However, if the building is located in a zone where outdoor advertising may be desirable in the future, the architect should provide one or two 2-inch conduits for circuits leading from the main switchboard to the roof, through which wires may be pulled later. Where this illumination has been determined upon, the architect should confer with the representative of the advertising agency that is to lease the space and erect the devices, in order to secure the exact data required.

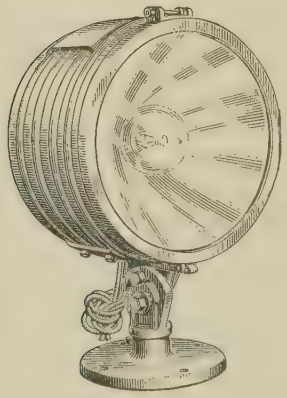


FIG. 50

One form of exterior illumination for a building is called *flood lighting* and consists of directing rays on a building from

gas-filled mazda lamps located some distance from the building and mounted in a projector or reflector as shown in Fig. 50.

61. Show windows that are to be illuminated should have the lamps connected to special cut-out panels supplied from special feeders, because these windows are frequently lighted at hours when the remainder of the building is dark. In addition to the outlets for permanent show-window fixtures, it is well to have attachment-plug receptacles for connecting portable lamps, decorative lamps, and mechanical advertising devices. Extreme care should be taken that the wiring and fixtures in show windows are installed in accordance with the Code to avoid danger from overheated lamps or wires.

LOW-VOLTAGE WIRING

LOW-VOLTAGE SYSTEMS IN GENERAL

SOURCES OF LOW-VOLTAGE ENERGY

62. Definition and Classification.—The expression *low voltage wiring,* as used in this Section, refers to voltages rang-

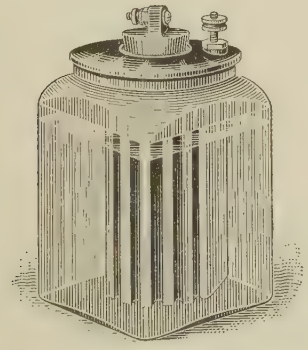


FIG. 51

FIG. 52

ing from 10 to 30, as used for signal, alarm, and bell wiring, although the underwriters define a low-potential system as one operating at 600 volts or less.

63. Primary batteries are classed according to construction as *wet batteries* and *dry batteries*. Of wet cells the ordi-

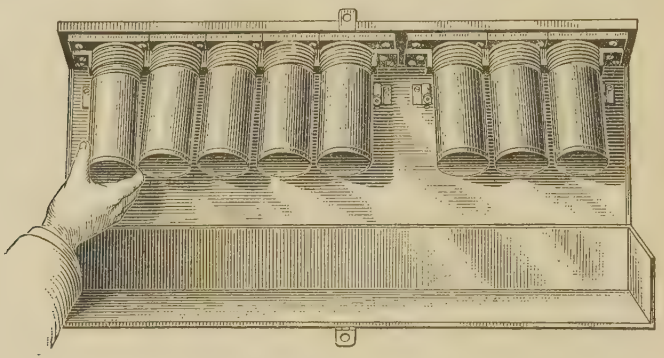


Fig. 53

nary sal-ammoniac cell as shown in Fig. 51 is one of the most widely used. Because of their greater convenience and adaptability, dry cells are replacing wet cells for the smaller open-circuit system. The dry cell works on practically the same chemical principle as the sal-ammoniac cell, the essential difference being that the former is non-spillable. The dry cell is

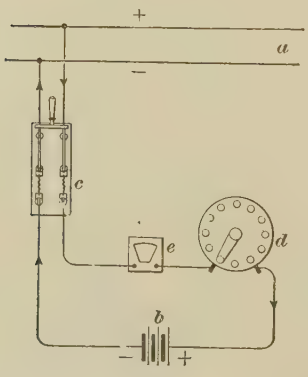


Fig. 54

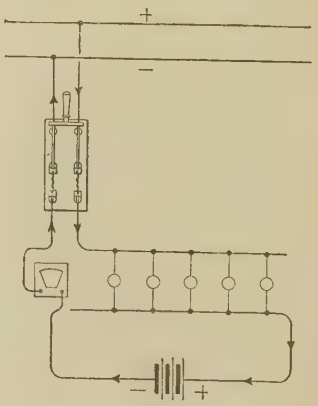


Fig. 55

familiar to every one; a convenient type has a screw top, as shown in Fig. 52, similar to the base of an Edison lamp, and

can be screwed into a receptacle in a cabinet of special design, as in Fig. 53.

64. Storage Batteries.—The installation of a storage battery may be advisable in a building where many low-voltage devices are to be used, as in a hotel. With it must be the necessary switches, resistors, and regulators for recharging. Storage batteries are rated in ampere-hours, the product of the discharge rates in amperes and the number of hours that rate will be maintained without material decrease if the battery is fully charged at the outset. For example, a battery that will

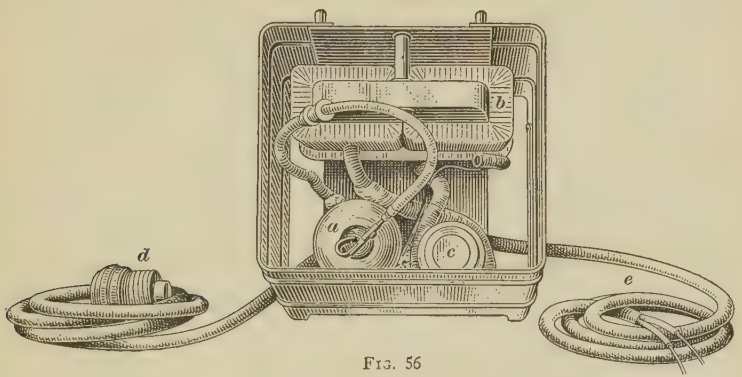


FIG. 56

discharge 5 amperes steadily for 8 hours through a circuit of fixed resistance is a 40-ampere-hour battery.

65. When the voltage of a storage battery begins to fall rapidly, the battery is said to be discharged, and it must be recharged before further use. A small battery can be charged from a direct-current lighting circuit by connecting an adjustable resistor in series with the battery to regulate the charging current. Fig. 54 shows typical connections; the lighting circuit is represented at *a*, the battery at *b*, the switch at *c*, the adjustable resistor at *d*, and an ammeter at *e*. A group of electric lamps, forming a *lamp bank*, can be used for a resistor, as shown in Fig. 55, and the current can then be regulated by screwing in or out of their sockets one or more lamps.

66. If the lighting current is alternating it must be converted, or rectified, for charging a battery. For a small battery a tungar rectifier, Fig. 56, may be used. It consists of a rectifier bulb *a*, a compensator *b*, a fuse and receptacle *c*, alternating-current leads *d*, and direct-current leads *e*. The bulb is shown separately in Fig. 57, a tungsten filament being shown at *a*, and an anode consisting of a piece of graphite at *b*. A diagram of the connections is shown in Fig. 58. When using the rectifier, care must be taken to see that the direct-current leads are properly connected to the battery terminals according

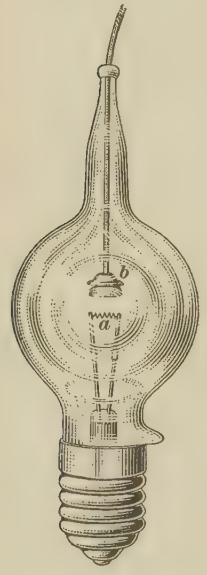


Fig. 57

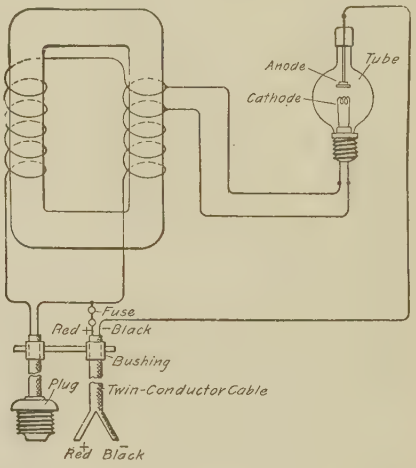


Fig. 58

to polarity, and the plug on the alternating-current leads may then be screwed into a socket on a circuit of the right voltage. Large batteries are sometimes charged by means of motor-generators, each consisting of an alternating-current motor driving a direct-current generator.

67. Low-Voltage Alternating-Current Devices.—House bells and other low-voltage devices may be operated by alternating current, which can be obtained from the lighting circuits by the use of bell-ringing transformers.

GENERAL REQUIREMENTS FOR LOW-VOLTAGE WIRING

68. Installation Requirements.—Because of the low voltages and small currents carried by signal and alarm circuits, the conductors need not be so large nor so thoroughly insulated as those in power-and-lighting work. Yet, owing to the lack of strength of the small conductors and to the large number necessary in the more complicated systems, low-voltage wiring should be planned as carefully as light-and-power work. In dry wood-frame buildings the joists should be bored and the wires run through them. No protection except the insulation is necessary in this class of work. Metal staples, even when insulated, sometimes corrode the wires. Where wires are run open they can be fastened directly on the framing by means of fiber or compressed-wood cleats, insulated nails, or staples with an insulating saddle. Holes are cut at desired points and the wires brought out to push-buttons, bells, or other appliances. In finished buildings of wood-frame construction, the wires can be fished between the studs or joists or run along picture molding or the tops of baseboards. Concealed signal wires should not be fastened with metal.

69. In fireproof buildings, with no available hollow spaces, complete conduit or duct systems are installed within which are placed the wires of the low-voltage circuits. Low-voltage circuits cannot be run in the same conduits with lighting circuits. Where a conduit system is laid out, suitable outlet boxes or conduit fittings similar to those used for lighting work are provided, and pull boxes or junction boxes are installed where necessary. Also interconnection boxes, or cabinets, containing interconnection boards are installed at junction points.

70. Conductors for Low-Voltage Wiring.—For small low-voltage lines in dry places in wood-frame buildings wires with a paraffined double-cotton braiding can be used. For damp places in such buildings and for small lines originating at interconnection boxes in larger installations, braided twisted pairs with rubber insulation are used. Where a comparatively large number of wires must follow the same run, it is better to

employ cotton-, silk-, or paper-insulated conductors twisted together in pairs and covered with an outer wrapping and a sheathing of lead. Conductors with cotton or silk insulation are generally used for cables of medium diameter and length, and paper-insulated conductors for larger cables such as telephone cables.

SIGNAL APPLIANCES AND SIMPLE BELL SYSTEMS

BELLS AND SWITCHES

71. Electric bells are of two general classes, vibrating bells and single-stroke bells. A **vibrating bell** is one with a hammer or tapper that vibrates as long as the bell receives current. A **single-stroke bell** is one that gives only a single tap, no matter how long the bell circuit is kept closed. A **continuous-ringing relay,** or **drop,** is a device connected in the

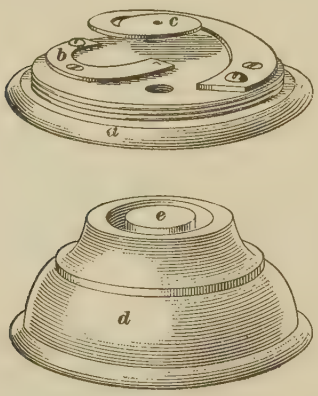


FIG. 59

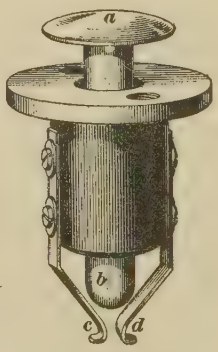


FIG. 60

circuit to a vibrating bell in such a manner that the bell continues to ring after the push button has been released by the operator. The bell rings until the relay is reset.

72. An **electric horn** is a device with a metal diaphragm arranged to be set into vibration by electromagnets or by an electric motor. They are most commonly used on automo-

biles, but they are also used to some extent to replace whistles in factories. An **electric whistle** is a valve electromagnetically operated to control the passage or air or steam to a whistle. An **electric buzzer** is essentially the same as an electric bell, except that the hammer and gong are omitted. A buzzer is used where the loudness of the bell is unnecessary, or might be undesirable.

73. Switches, commonly called *push buttons,* or *bell buttons,* for operating electric bells, buzzers, and other low-voltage devices are made in the forms shown in Figs. 59, 60, and 61. In Fig. 59 the base for attaching to a wall, table, desk, etc., is shown at *a,* the two contacts at *b* and *c,* the cap at *d,* and the button at *e.* In the floor-type button shown in Fig. 60 the button *a* can be depressed so that plunger *b* will close the circuit between the contacts *c* and *d.* In Fig. 61 is shown a button with a clamp for the edge of a table or desk. Bell buttons are available in groups so that several different signals may be given from one point, as from the desk of a manager or superintendent, who may wish to call an assistant.

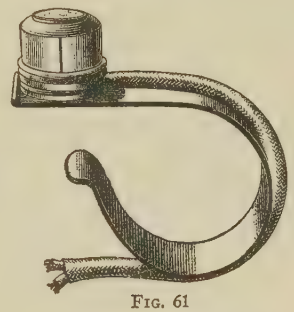


FIG. 61

CALL-BELL SYSTEMS

74. Call-bell systems are possible in many forms, varying from the simplest system consisting of one bell and one push button, to complicated systems including one bell and many buttons, or a multiplicity of both bells and buttons in the same system. The average dwelling has a bell that may be rung from the front or rear door, or possibly a separate bell or buzzer would be provided for each door. There is also usually a floor push button in the dining room, for ringing a buzzer in the kitchen.

75. In Fig. 62 is shown a push-button and speaking-tube mouthpiece in connection with a mail box. This type of fixture is commonly used in small apartment houses having no elevator service or lobby attendant. A visitor in the vestibule of the main entrance can ring a bell in the apartment he wishes to visit. When he has the attention of some one in the apartment, he announces himself through the speaking-tube. The person in the apartment then presses a button that sends current to an automatic electric door-opener in the frame of the inner door of the main vestibule. This door-opener releases the lock and allows the visitor to enter. Buzzer buttons may also be placed in the public hall on each floor of the house, so that the visitor may announce his arrival at the apartment door.

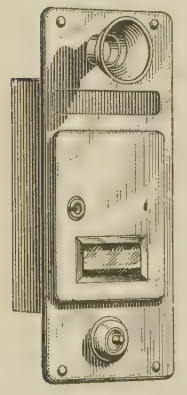


FIG. 62

ANNUNCIATORS AND THEIR USES

76. When one electric bell can be rung from any of a number of places, as from different rooms of a hotel or from different entrances to an elevator shaft, a device called an *annunciator,* Fig. 63, is installed to indicate the location of the person signaling. Annunciators depend on the movement of a pointer, drop, or shutter by the action of an electromagnet that receives current when the corresponding push button is operated.

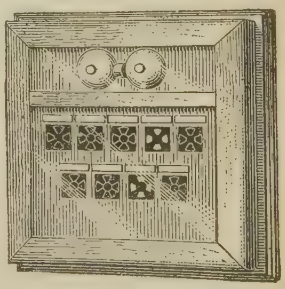


FIG. 63

77. A mechanical-reset annunciator as shown in Fig. 64 is one in which after every signal each indicator must be restored by hand to its normal position. This is done by manipulating a push rod at the bottom of the annunciator. Such an annunciator has two pronounced disadvantages; it must be mounted within reach and

in a readily accessible place, and if the indicator is not reset promptly after each call, confusion is very likely to result.

78. In electrical-reset annunciators that are reset electrically the indicators are restored by pressing a key or a push button controlling a current through reset windings on the electromagnets. It must also be reset promptly after each call, but it can be mounted out of reach and reset from any convenient place. Automatic-reset annunciators are also operated electrically, but they require no manipulation on the part of an attendant, all indicators of previous calls being reset automatically by the last call which is the only call that indicates.

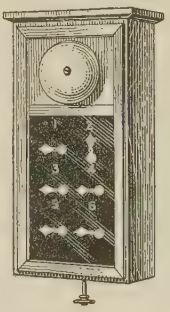


FIG. 64

79. Return-call annunciators are provided with keys so that a person at either end of a line can be signaled that the call has been heeded. Such annunciators are useful in hotels having no interior telephone system and in any building, like an apartment house, having a speaking-tube system.

80. In the lamp annunciator, the signaling station is indicated by the lighting of a small incandescent lamp. The system is wired so that the annunciator bell stops ringing as soon as the caller releases his push button, but the lamp burns until the call is answered.

81. A large number of passenger elevators are equipped with annunciators having small battery lamps instead of names or numerals. White lights are used to indicate floors from which passengers wish to ascend, and red lights indicate those from which they wish to descend.

BURGLAR-ALARM SYSTEMS

82. A burglar-alarm system includes essentially a source of electricity, a bell, an annunciator, and various devices placed about the building in such a manner that an intruder will make the system operative. The bell sounds the alarm and the annunciator indicates the location at which the intruder is trying to enter. Devices for detecting the entrance of a burglar are made in many forms adapted for various purposes. Some are designed to be operated by the raising of a window or by the opening of a door, where entrance is likely to be attempted.

Bells for burglar alarms should be either of the continuous-ringing type or controlled by a continuously-ringing relay. Otherwise, an entrance might be made so quickly that the bell would not ring long enough to arouse the occupants of the building.

FIRE-ALARM SYSTEMS

83. The fundamental fire-alarm system consists of a number of signal boxes from each of which the alarm bell can be sounded. A simple system well adapted to a small loft building with three or four floors, or to a one-story building with considerable floor area, is installed by placing on each floor or in each room or department a bell to give the alarm, and an annunciator to indicate the location of the station from which the alarm was sent.

84. The alarm boxes of larger systems are generally semi-automatic in operation. The turning of the key or the pulling of a small lever releases a clockwork mechanism propelling a contact maker or breaker, as the case may be. Each time the contact maker acts, the alarm bell is tapped once, and the number of the station is thus signaled. For example, two taps, a pause, and then three taps is the signal from station No. 23. The box mechanism is automatically arranged to send the signal three times. The mechanisms of such boxes are arranged so as to be non-interfering. If persons at two dif-

ferent stations should start the mechanisms simultaneously, the signals would not conflict but would be received one at a time.

85. The fire-alarm system of the I.C.S. instruction building and printery, a typical modern installation, employs boxes working on the principle just described. Instead of a bell, however, the alarm consists of a whistle electrically operated. The system is connected to the city fire-alarm telegraph system, two outside circuits being run, one directly to a nearby engine house and the other to the city fire headquarters from which it is relayed to all battalion chiefs and companies that respond to alarms in the I.C.S. zone. In a locked cabinet, to which only the fire marshal or one of his lieutenants holds the key, is mounted a switch for making silent tests of the system or sounding an alarm for a fire drill. The test switch is wired so as not to operate the city alarms. Fire-alarm systems of this type are built for both direct and alternating current.

86. The so-called *thermostat systems* are automatic in operation. At various places in a building are thermostats or thermostatic switches, constructed so as to close automatically a circuit whenever the temperature reaches a dangerous degree.

MISCELLANEOUS LOW-VOLTAGE EQUIPMENT

ELECTRIC CLOCKS

87. A watchman's clock consists of an electromechanism so arranged that an electric current or impulse causes a mark to be made on a paper dial rotated by a clock movement. Watchman's stations are located in various places that the watchman is supposed to visit. The watchman carries a switch handle, or key, with which, at each station, as he visits them in regular order, he is enabled to send a brief current through the clock mechanism. The clock itself is usually located in the main office where the watchman cannot get to it. This furnishes a system by which the movements of the watchman may be known with certainty, for, if he fails to visit a station at

the appointed time, the absence of a corresponding mark on the clock dial will expose his failure.

88. Electric uniform-time clocks are used in large establishments where it is desirable that the same time shall govern employes, guests, or tenants in a number of rooms or buildings. A master clock is located at a convenient place and at regular intervals, usually once each minute, operates an electric circuit that passes through a series of secondary clocks located wherever desired, and thus moves the hands of each clock in the circuit.

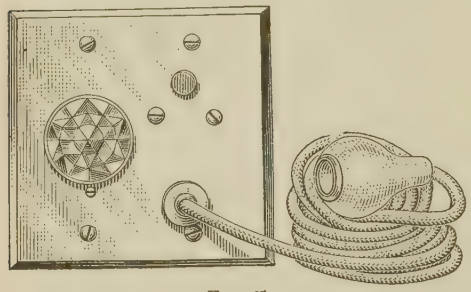


FIG. 65

NURSES' AND MAIDS' CALL SYSTEMS

89. Nurses' signal systems are used in hospitals to enable patients to call nurses. By pressing a button in a pendent switch extended from a special wall-plate, Fig. 65, a patient lights a lamp in an annunciator, Fig. 66, in the nurses' duty room, a corridor, Fig. 67, outside the door of the ward room, and another lamp in the wall-plate that is near the head of the patient's bed, and at the same time sounds a buzzer in the duty room and one in the diet kitchen. The system is non-interfering, as pressing a reset button extinguishes only those lamps that are controlled from the button operated by the patient. The buzzers sound only momentarily, but they sound each time the patient presses the bedside button. In a room with only one bed the lamp in the wall-plate can be omitted without causing inconvenience.

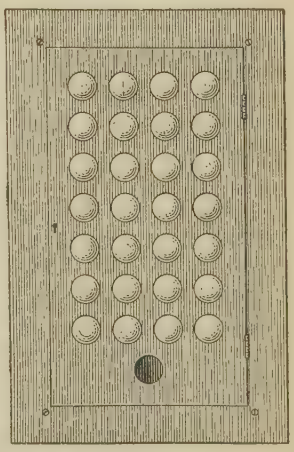


FIG. 66

90. Maids' location and call systems for hotels are arranged so as to inform the room clerk or the floor clerk as to the room or suite in which the maid is working. When a maid enters a room, she inserts a lamp in a special receptacle in the corridor wall near the door of the room. The lighted lamp informs any one in the corridor of the maid's location, and at the same time a circuit is completed that shows the room number on an annunciator at the desk of the room clerk or the floor clerk. Thus, if the services of the maid are required elsewhere at short notice, she can be called immediately over the house telephone

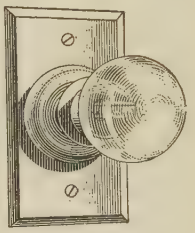


FIG. 67

TELEPHONE WIRING

TELEPHONE SYSTEMS IN GENERAL

91. Telephone equipment ranges, according to the nature and the size of the building, from a single instrument to several hundred. There are three general plans of connecting the instruments in a building requiring a number of telephones: the switchboard system, the intercommunicating system, and the party-line system.

92. A **switchboard system,** frequently called a private-branch exchange system, to distinguish it from the public-exchange system, includes a special telephone switchboard from which lines radiate to the various instruments, and at which are made the connections enabling persons to talk to one another. An **intercommunicating system,** sometimes called a house system, employs no central switchboard; switching devices located at each telephone station provide a means enabling a person at any station to call every other station on the system. The **party-line system,** as now commonly used, refers to the connection of from two to four subscribers on one trunk line from a public exchange, none of the subscribers

being able to call another on the same party line, except through the central exchange. The **local-battery party-line** system, using a magneto for ringing and local batteries for talking, enable a person to call another without the assistance of the central station. The local-battery party-line system is now rarely installed except in rural districts.

93. The switchboard system is generally used in hotels or other large public buildings and for groups of buildings having a large number of telephones and consequently a large number of calls. The intercommunicating systems are very useful for internal service in residences, apartment houses, stores, offices, schools, banks, etc., in general, whenever the number of telephones is small and the calls infrequent. Telephone switchboards are of three fundamental types, manual, automatic, and semiautomatic. The choice among these three types is governed by the kind and size of the business to be served, and the problem is one to be solved by a telephone specialist. All the architect need know is the size and location of the switchboard, in order that he can, if necessary, make special provision for it.

TELEPHONE EQUIPMENTS AND WIRING METHODS

94. Residences.—Provisions for telephone wiring are seldom necessary in small residences because the one telephone generally used in each residence can be readily installed after the building is completed. Even in such a building, however, provision for telephone wiring may be made at small additional expense. For a large residence in which several telephones are to be installed, provisions for the telephone wires should be made in the design. After the locations of the telephones have been determined, the plans should be marked with the routes of the rigid conduits in which the wires are to be carried, and the location of the telephone outlets should be indicated as closely as possible. Floor outlets should be provided for portable, or desk, instruments. The cabinets of so-called flush-type instruments are set in the wall, and provision must be made accordingly. For a house system using not more than

six telephones, $\frac{3}{4}$-inch conduit is large enough; in larger systems, the size of the conduit must be greater, because a pair of wires is in some cases required for each telephone.

95. Hotels, Apartment Houses, Etc.—In large buildings where extensive telephone service is to be installed, provision must be made for the wiring and for a switchboard. In a hotel the switchboard is usually located in or near the office. A pair of wires from each room or suite connect near the switchboard with a common center called a main terminal box. From the switchboard the trunk wires run to the point at which the telephone cable enters the building, generally in the basement. From the main terminal box, cables containing the twisted pairs are carried up vertical pipe-shafts to terminal boxes located on the various floors. From each of the terminal boxes a conduit system is run to designated locations in the rooms.

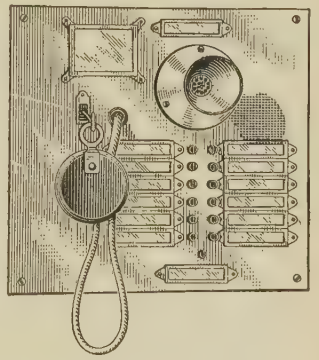


FIG. 68

96. In apartment houses, where only one telephone for each apartment is required, a simple method of wiring is to carry a vertical conduit up through each tier of apartments, and to provide an outlet in each apartment. Individual twisted pairs of rubber-covered wire may then be pulled through this conduit for each telephone. The individual wires can be carried in a cable from the bottom of each riser to the switchboard, which is generally located in the main hall. Small apartment houses without hall attendance do not have telephone switchboards, but employ modifications of the intercommunicating system. In each vestibule is a vestibule set, or tradesmen's set, similar to the flush wall set shown in Fig. 68, comprising a transmitter (mouthpiece), a receiver, a nameplate for each apartment and one for the janitor, and a corresponding push button for connecting with any apartment or with the janitor's office. In the janitor's office is a similar equipment,

together with an annunciator to show the janitor which apartment or which vestibule is calling. The apartment set, of which the flush wall instrument shown in Fig. 69 is an example, does not differ from the ordinary telephone except that it has a button for calling the janitor. Another type of apartment set has, in addition, a button for operating an automatic door-opener.

97. Office buildings, department stores, and other large buildings usually have public-service telephone systems and are frequently very complex. It is customary for the architect to confer with the telephone company's engineer relative to the telephone requirements of the building and the service the company will give. By such a conference the best location of the wire shaft, distributing boards, junction boxes, and telephone outlets may be determined and the most effective system and consequent economical installation secured. The owner of the building will be required to provide all conduits and accessories, including cases for terminals, junction boxes, etc. The telephone company will provide and install the wiring, terminals, and the individual telephones.

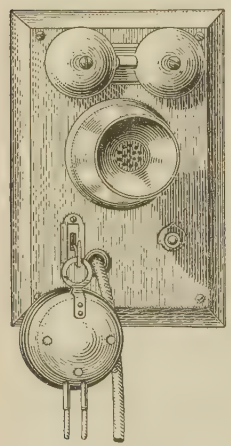
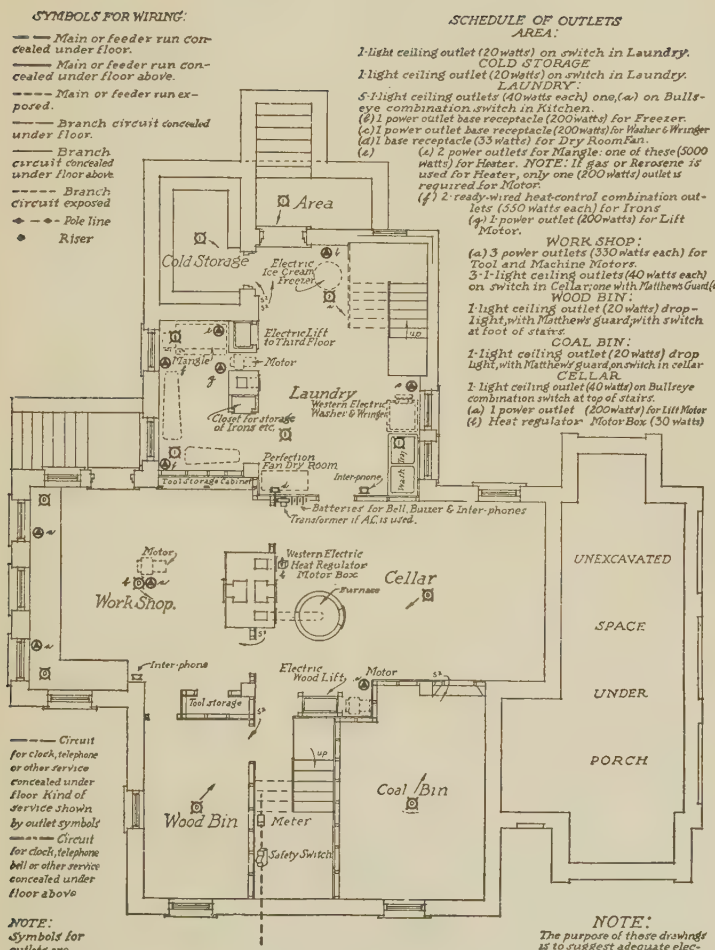


FIG. 69

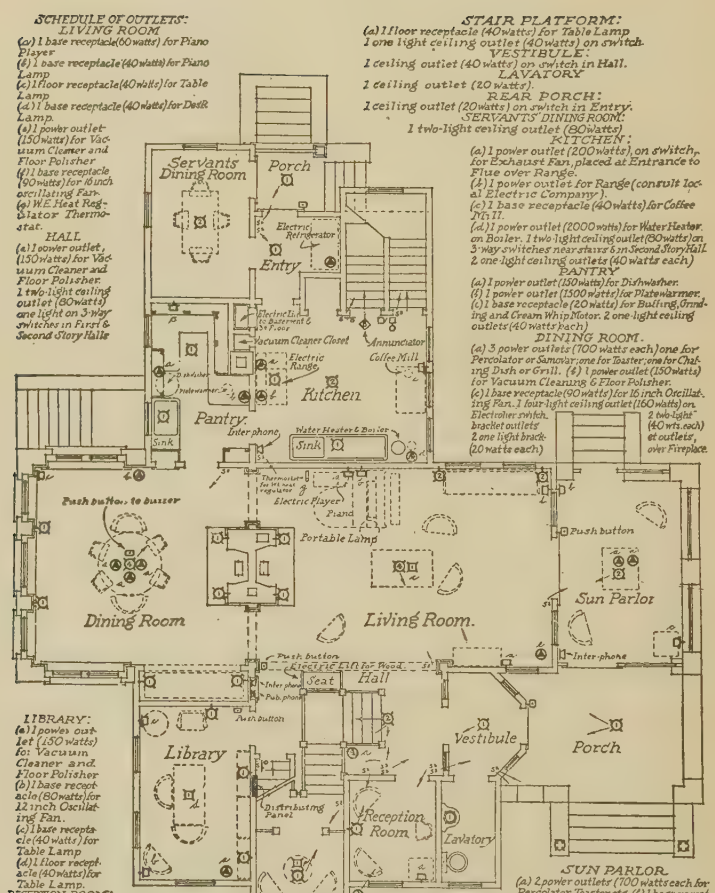
98. In Figs. 70 to 73 are given plans of a dwelling house fitted up with all the electrical appliances that it is possible to show in such a house. It is not likely that these appliances would all occur in any one house, but the diagrams are given to show the application of such devices in fitting up a modern dwelling. The several appliances are indicated by symbols which, with slight variations, are those agreed on by the American Institute of Architects and the National Electrical Contractors' Association, but are subject to change and revision from time to time. These symbols are shown in Fig. 74.

The symbols shown in Fig. 74 are the ones most generally used at the present time. A new set of symbols, shown in



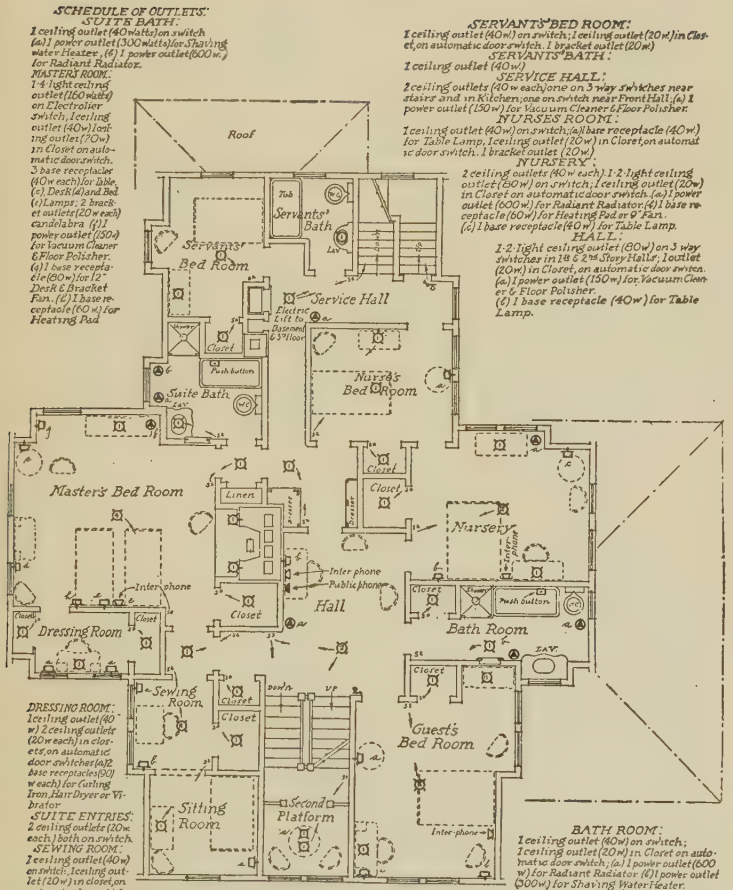
Courtesy of the Habirshaw Electric Cable Co., Inc.

FIG. 70



Courtesy of the Habirshaw Electric Cable Co., Inc.

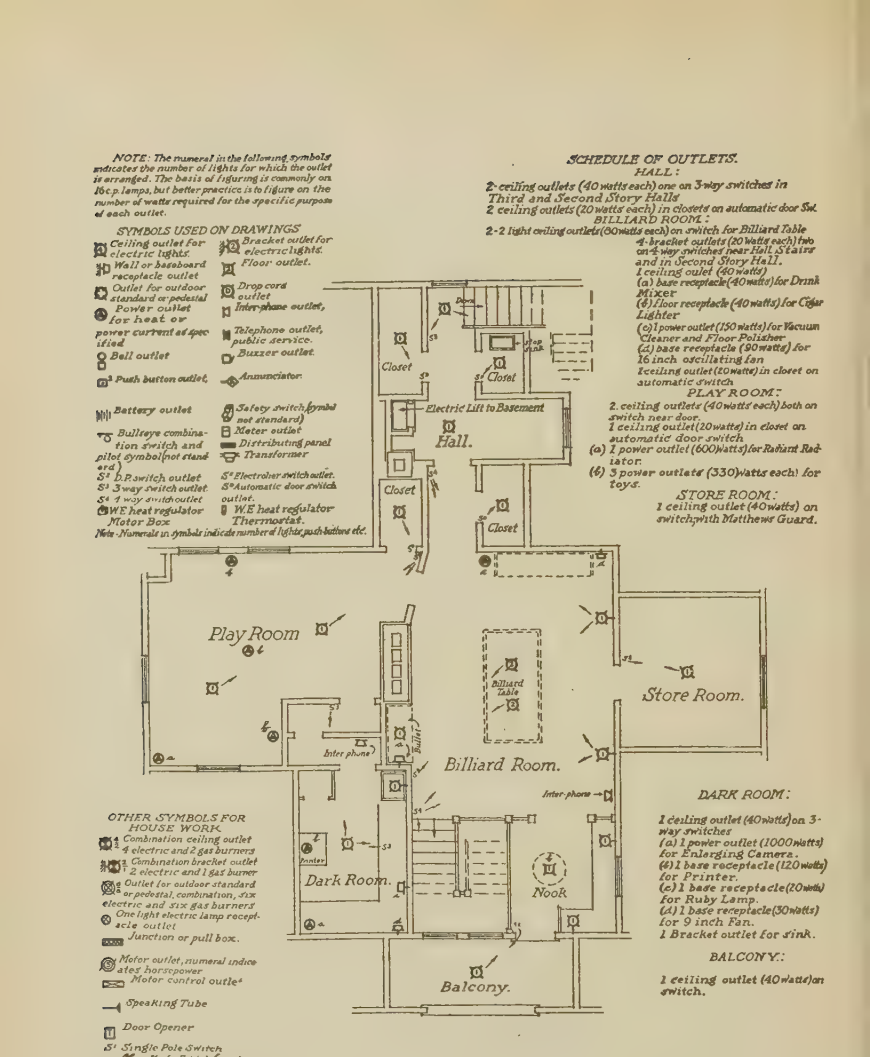
FIG. 71



Second Floor Plan

Courtesy of the Habirshaw Electric Cable Co., Inc.

FIG. 72



Third Floor Plan

Courtesy of the Habirshaw Electric Cable Co., Inc.

FIG. 73

ELECTRICAL INDICATIONS

Ceiling outlet; electric only. Number of center indicates number of standard 50 watt electric lamps

Ceiling outlet; combination 4/2 indicates 200 watt electric light capacity and 2 gas burners

Bracket outlet; electric only. Numeral in center indicates number 50 watt electric lamps

Bracket outlet; combination 4/2 indicates 200 watt electric light capacity and 2 gas burners

Show as many symbols as there are switches, or in case of a very large group of switches indicate the number of switches by a Roman numeral, thus: S[1] XII means 12 single pole switches.

Describe type of switch in specifications, that is flush or surface, push button or snap.

Wall or baseboard receptacle outlet: Numeral in center indicates number of standard 50 watt electric lamps

Floor outlet: Numeral in center indicates number of 50 watt electric lamps

Outlet for outdoor standard or pedestal; electric only. Numeral indicates number of 50 watt electric lamps

Outlet for outdoor standard or pedestal: Combination 6/6 indicates 300 watt electric light capacity lamps, 6 gas burners

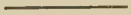
Special outlet for lighting, heating or power current as described in specifications

Drop cord outlet

One light outlet for lamp receptacle

Arc lamp outlet

Main or feeder run under floor concealed



Main or feeder run concealed under floor above

Main or feeder run exposed

Branch circuit run concealed under floor

Branch circuit run concealed under floor above

Branch circuit run exposed

Pole line

Riser

Telephone outlet; Private service

Telephone outlet; Public service

Bell outlet

Buzzer outlet

Push button outlet; Numeral indicates number of pushes

Annunciator; Numeral indicates number of points

Speaking tube

Watchman clock outlet

Watchman station outlet

Master time clock outlet

Secondary time clock outlet

Single Pole Switch outlet .....

Double Pole Switch outlet .....

3-way switch outlet.

Automatic door switch outlet .....

Electrolier switch outlet .....

Show as many symbols as there are switches, or in case of a very large group of switches indicates the number of switches by a Roman numeral thus: S^{1} XII means 12 single pole switches. Describe type of switch in specifications, that is flush or surface, push button or snap

Meter outlet

Distribution panel

Junction or pull box

Motor outlet: Numeral in center indicates horse power

Motor control outlet

Transformer

Circuit for clock, telephone, bell or other service run under floor concealed. Kind of service wanted ascertained by symbol to which line connects

Circuit for clock, telephone, bell or other service run under floor above, concealed. Kind of service wanted ascertained by symbol to which line connects

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FIG. 74

Special outlet; signal system as described in specifications

Battery outlet

NOTE: If other than standard 50 watt electric lamps capacity is desired specifications should describe capacity of lamp desired

SUGGESTIONS IN CONNECTION WITH STANDARD SYMBOLS FOR WIRING PLANS

It is important that ample space be allowed for the installation of mains, feeders, branches and distribution panels.

It is desirable that a key to the symbols used accompany all plans

If mains, feeders, branches and distribution panels are shown on the plans it is desirable that they be designated by letters or numbers.

Heights of center of wall outlets; (unless otherwise specified)

Living rooms	5′-6″
Chambers	5′-0″
Corridors	6′-3″
Offices	6′-0″

Heights of Switches (unless otherwise specified) 4′-0″

Fig. 75, was recommended and adopted by the Association of Electragists, International; The American Institute of Architects; and the American Institute of Electrical Engineers; and approved by the American Engineering Standards Committee on March 6, 1924. These later symbols have not yet come into universal use. There is no doubt, however, but that they will be used more and more in the course of time, and will ultimately supersede those given in Fig. 74. This new system is therefore given so that, if the symbols are found on plans, they may be understood.

99. As stated in the note on Fig. 70, the drawings are intended to show diagrams of the various floor plans and the customary application of symbols to the rooms usually found in such a residence. A careful study of these plans in connection with the symbols given on the illustrations and in Fig. 74, will furnish an excellent idea of the complete fittings for a house. Symbols have not been standardized for some devices, such as the safety switch shown in Fig. 70. Architects and engineers who use special symbols not indicated in Fig. 74, or who may use other systems of symbols, generally show on one or more of the plans a list of the symbols used for the guidance of the wireman.

100. In Fig. 76 is shown a portion of a plan of a hotel building. In this plan all the outlets, as well as the wires supplying these outlets, are shown. Panel-boards from which these wires receive the current from the feeders are also shown. In the room *D* will be found indications of ceiling lights with two lights at *a*, wall brackets containing two lights at *b*, a base outlet for one light at *c*, and a floor outlet for two lights at *d*. At *e* are shown switches, one of which controls the two side outlets *b* and another switch controlling the ceiling outlet *a*. A secondary clock is shown at *f*, and a telephone outlet is shown at *g*. These indications are all shown in accordance with the list of symbols given in the upper right-hand corner of the figure. The indications are practically the same as in Fig. 74.

101. The wiring from the floor outlet *d*, Fig. 76, to the base outlet and through the point *h* and to the panel-board, is

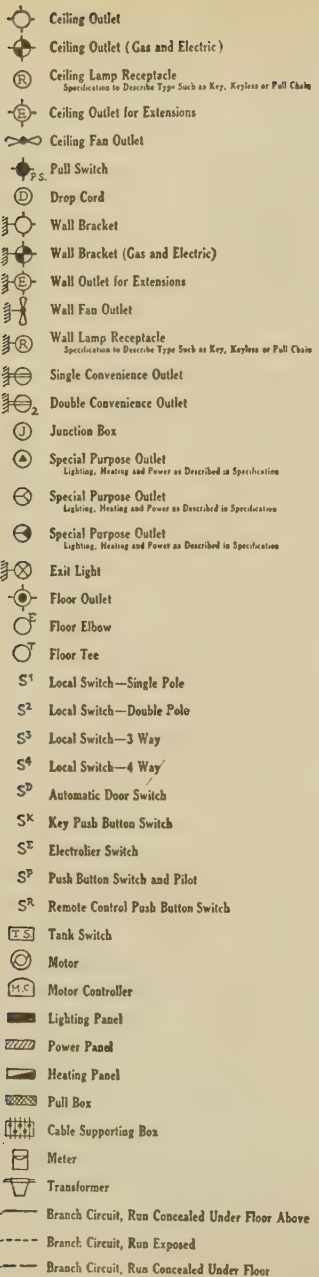
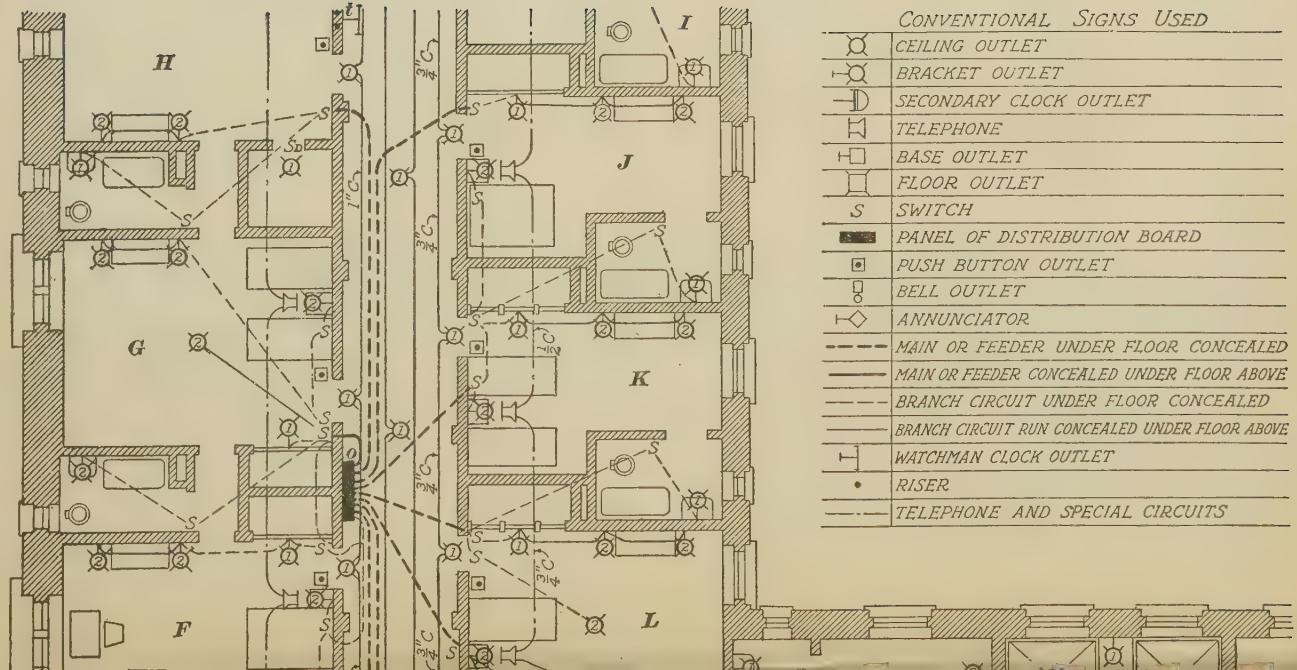

Ceiling Outlet
Ceiling Outlet (Gas and Electric)
Ceiling Lamp Receptacle
Specification to Describe Type Such as Key, Keyless or Pull Chain
Ceiling Outlet for Extensions
Ceiling Fan Outlet
P.S. Pull Switch
D Drop Cord
Wall Bracket
Wall Bracket (Gas and Electric)
Wall Outlet for Extensions
Wall Fan Outlet
Wall Lamp Receptacle
Specification to Describe Type Such as Key, Keyless or Pull Chain
Single Convenience Outlet
2 Double Convenience Outlet
J Junction Box
Special Purpose Outlet
Lighting, Heating and Power as Described in Specification
Special Purpose Outlet
Lighting, Heating and Power as Described in Specification
Special Purpose Outlet
Lighting, Heating and Power as Described in Specification
Exit Light
Floor Outlet
F Floor Elbow
T Floor Tee
S1 Local Switch—Single Pole
S2 Local Switch—Double Pole
S3 Local Switch—3 Way
S4 Local Switch—4 Way
SD Automatic Door Switch
SK Key Push Button Switch
SE Electrolier Switch
SP Push Button Switch and Pilot
SR Remote Control Push Button Switch
TS Tank Switch
Motor
MC Motor Controller
Lighting Panel
Power Panel
Heating Panel
Pull Box
Cable Supporting Box
Meter
Transformer
Branch Circuit, Run Concealed Under Floor Above
Branch Circuit, Run Exposed
Branch Circuit, Run Concealed Under Floor
This Character Marked on Tap Circuits Indicates 2 Number 14 Conductors in ½" Conduit
This Character Marked on Tap Circuits Indicates 3 Number 14 Conductors in ½" Conduit
This Character Marked on Tap Circuits Indicates 4 Number 14 Conductors in ¾" Conduit Unless Marked ½"
This Character Marked on Tap Circuits Indicates 5 Number 14 Conductors in ¾" Conduit
This Character Marked on Tap Circuits Indicates 6 Number 14 Conductors in 1" Conduit Unless Marked ¾"
This Character Marked on Tap Circuits Indicates 7 Number 14 Conductors in 1" Conduit
This Character Marked on Tap Circuits Indicates 8 Number 14 Conductors in 1" Conduit
NOTE—If larger conductors than number 14 are used, use the same symbols and mark the conductor and conduit size on the run.
Feeder Run Concealed Under Floor Above
Feeder Run Exposed
Feeder Run Concealed Under Floor
Pole Line
Push Button
Buzzer
Bell
Annunciator
Interior Telephone
Public Telephone
Clock (Secondary)
Clock (Master)
Time Stamp
Electric Door Opener
F Local Fire Alarm Gong
City Fire Alarm Station
F Local Fire Alarm Station
Fire Alarm Central Station
Speaking Tube
N Nurse's Signal Plug
M Maid's Plug
Horn Outlet
District Messenger Call
W Watchman Station
W Watchman Central Station Detector
P B X Public Telephone—P B X Switchboard
IX Interconnection Telephone Central Switchboard
Interconnection Cabinet
Telephone Cabinet
Telegraph Cabinet
Special Outlet for Signal System
As Described in Specification
Battery
Signal Wires in Conduit
Concealed Under Floor
Signal Wires in Conduit
Concealed Under Floor Above

FIG. 75



Conventional Signs Used

	CEILING OUTLET
	BRACKET OUTLET
	SECONDARY CLOCK OUTLET
	TELEPHONE
	BASE OUTLET
	FLOOR OUTLET
S	SWITCH
	PANEL OF DISTRIBUTION BOARD
	PUSH BUTTON OUTLET
	BELL OUTLET
	ANNUNCIATOR
	MAIN OR FEEDER UNDER FLOOR CONCEALED
	MAIN OR FEEDER CONCEALED UNDER FLOOR ABOVE
	BRANCH CIRCUIT UNDER FLOOR CONCEALED
	BRANCH CIRCUIT RUN CONCEALED UNDER FLOOR ABOVE
	WATCHMAN CLOCK OUTLET
	RISER
	TELEPHONE AND SPECIAL CIRCUITS

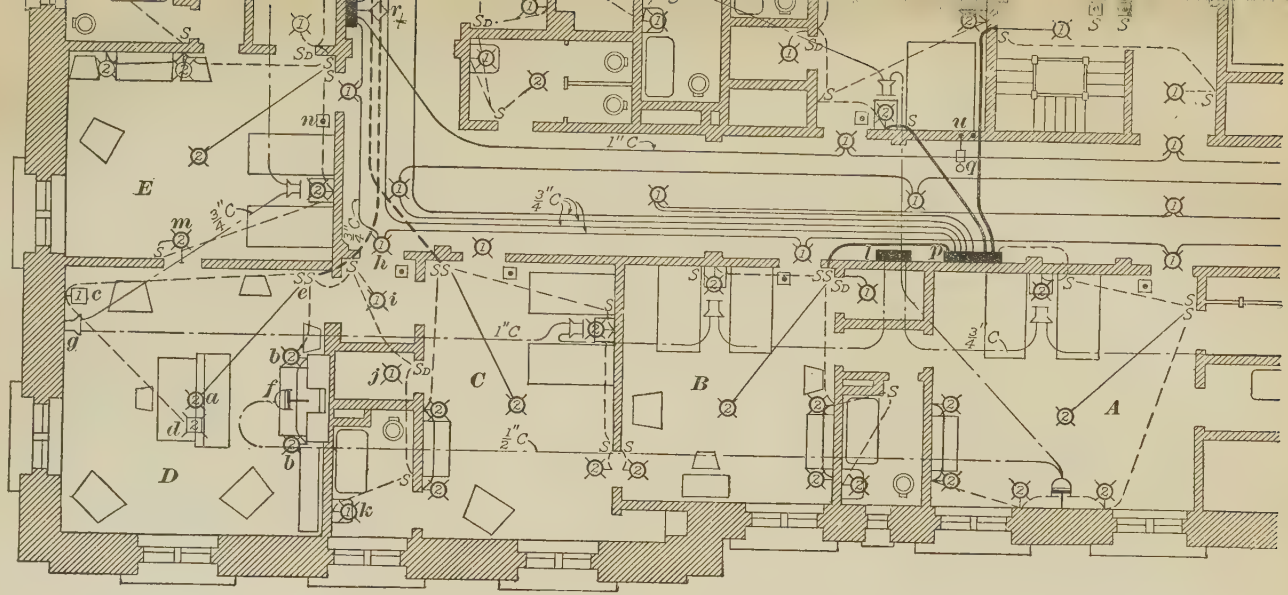


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Fig. 76

shown by a broken line indicating a branch circuit line run concealed under the floor. The side lights *b* are wired across the face of the chimney at a convenient place above these outlets, as shown by the solid line. This conduit then drops beneath the floor below and is indicated by a broken line the same as for the base and floor outlets. A conduit from the ceiling outlet *a* is shown solid, indicating that it is concealed in the floor above. This conduit drops to the floor at *e* and connects with the wire leading to the panel-board. The light *i* in the vestibule is also connected with this wire through the switch as shown. Additional lights at *j* and *k* are placed on this circuit. The light *j* is a closet ceiling light, and is operated by the door switch S_D, the current continuing through a switch to the lights *k*. The wiring for these lights and switches is carried beneath the floor, as indicated by the broken line. The wires from the lights *j* and *k*, notwithstanding the fact that they are on the same circuit as the lights in the room *D*, are controlled from the room *C*. In counting the lights on this circuit, it will be noted that outlets for twelve lights have been provided. The wiring for the secondary clock is shown by a dot-and-dash line, which indicates a clock, bell, telephone, or other service. This clock *f* is on the same circuit as the clock in the room *A*, and is connected with the panel-board *l*.

102. The telephone is on another circuit, and is connected with the telephone outlets in the other rooms, as shown on the drawings. This circuit also leads to the box *l*, Fig. 76. The box *l* is the terminal for low-voltage circuits such as telephones, clocks, etc. Similar telephone circuits also lead from this box to the telephone in rooms *M*, *L*, *K*, etc. Room *D* has lights placed on each side of the mantel. The outlet *a* is dropped from the ceiling and should be over the center of the room. The floor outlet *d* is designed to supply a special lamp placed near the center of the room. The base outlet *c* is designed to supply current to a floor light or lamp. In the bedroom *E* will be placed a ceiling light with two outlets, controlled by a switch near the entrance to the room, and there are two side outlets *q*, one on each side of a bureau or dressing

table. These lights are controlled by a switch at one side of the door, as shown. An outlet near the table between the beds provides for a lamp which may be placed on the table, controlled by a switch which can be reached from or controlled by a person lying in either bed.

103. An outlet *m*, Fig. 76, is placed where shown above the door between the rooms *D* and *E*. The object of this light is to enable persons to see themselves in a full-length mirror fitted in the door between these rooms. This light is controlled by a switch at one side of the door as shown.

104. Over the door between the rooms *B* and *C*, Fig. 76, two lights are shown. In this case a mirror is set in each side of the door. Over each door in the corridor is shown a ceiling-light outlet, the idea of the light being to locate the numbers on the doors easily, to furnish light by which a guest may see easily the number on the door, and to provide light in the room until the switch inside the door is located.

105. The panel-board *o*, Fig. 76, takes care of the circuits to the outlets for the rooms *D*, *E*, *F*, *G*, *J*, *K*, and *L*, and is placed centrally so that these circuits will be as short as possible to avoid unnecessary loss in voltage at the terminals of these circuits. Another panel-board, which takes care of the rooms in its vicinity, is shown at *p*. Additional ceiling lights are shown in the middle of the corridor, on two circuits, so that each alternate light or the entire series may be turned on, as desired. At *q* a bell is indicated which may be used for an alarm in case of fire. At *r* is an annunciator.

106. In the elevators are indications of drop lights in each car, which are connected with a flexible cord that moves up and down as the elevator rises or descends. An annunciator is shown in each elevator, which responds to the push button *s*, Fig. 76. At *t* is shown a watchman's clock, which is rung periodically at night by the watchman. At *u* two risers extend up through the building to feed the bell and other devices.

107. The sizes of some of the conduits are marked on the plan as shown. Thus, $\frac{3}{4}''c.$ indicates a $\frac{3}{4}$-inch conduit. The

symbols used in this plan are repeated in the upper right-hand corner of the illustration.

108. The lights in the elevators are on a circuit with the lights in the halls at the elevator. The lights in the elevators are taken off the circuit near the central floor of the building, half way in the height of the building. The circuit supplying the hall lights will, of course, occur on every floor.

109. A careful study of this plan, together with the table of symbols shown in Fig. 74, will give an excellent idea of the wiring of a large building. In a building of this kind care must be taken, first, to make the circuits as short as possible, so as to economize wire; and, secondly, to see that the number of lights on each circuit does not exceed the limit permitted by the Code.

HINTS ON WIRING

JOINTING

110. Jointing Conductors.—Whenever possible, joints in wires and cables should be avoided; but when unavoidable they should be made with the greatest care, for more fires are caused by defective electric connections than by inferior materials. In removing the insulation from wires preparatory to making a joint and in scraping the wire to clean it, great care should be taken not to nick the wires, thereby reducing both the carrying capacity and the mechanical strength. The cleaning should be thorough, preferably using sandpaper, in order to insure good electric connection and to permit the proper adhesion of the solder. Plain wire joints are shown in Figs. 77 to 79; joints of stranded conductors in Figs. 80 and 81.

FIG. 77

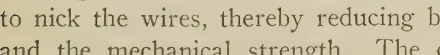


FIG. 78

Salts or acids should not be used for fluxes for soldering electric joints, because of their corrosive effect on copper and

insulation. Pure resin or powdered resin mixed into a paste with pure ethyl alcohol makes a harmless and efficient flux. The following formula for soldering fluid is also useful:

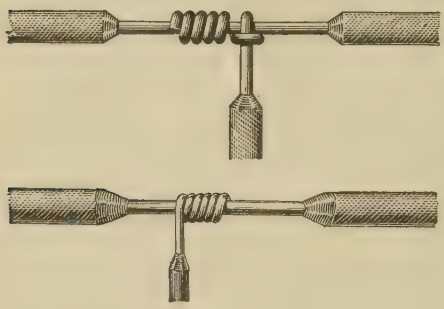


Fig. 79

Saturated solution of zinc chloride. 5 parts
Alcohol ..... 4 parts
Glycerine ..... 1 part

111. Insulation of Joints.—After soldering, the joint must be covered with insulation equivalent to that on the rest of the conductor. When joints in rubber-covered wires are to be insulated, two kinds of tape must be used; the first of pure rubber, and the second, called *friction tape*, of cloth saturated with moisture-proof adhesive material. The rubber tape can be obtained specially prepared by treatment with a chemical that renders the tape soft and adhesive on one side, or layers of pure rubber tape can be cemented together by rubber solution (cement) while the joint is being wrapped. The tape should be wound on spirally, stretching it all the time to make the completed joint as firm as possible. Rubber cement, if used, should be allowed

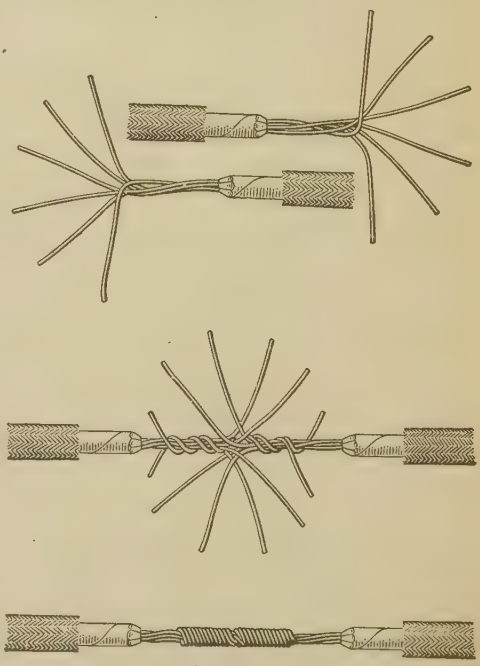


Fig. 80

to become almost dry before the next layer of tape is applied. The outer braided covering of the wire must be removed for a distance of at least 1 inch each way from the bare copper before the rubber tape is applied, because the rubber cement will not adhere to the braid. When the rubber tape has been wrapped on to a thickness a little greater than the insulation on the rest of the conductor, one or two layers of friction tape are applied, chiefly to give mechanical strength. Joints insulated by this method will be satisfactory under ordinary service conditions.

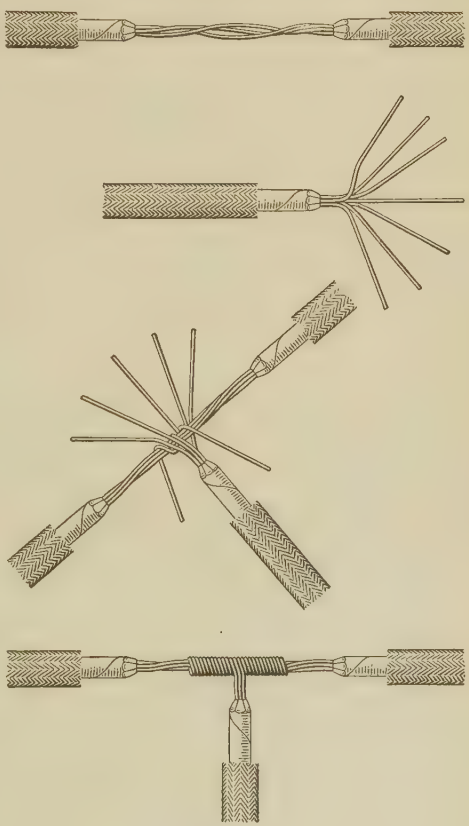


FIG. 81

112. In some cases specifications for interior wiring require that every joint shall be vulcanized. This process consists in converting, or curing the layers of strip insulation on the joint into a homogeneous coating that is continuous with the rubber covering of the manufactured cable. A joint to be vulcanized is first covered with a single layer of pure rubber tape and then with one or more layers of a special vulcanizing tape composed of rubber compounded with sulphur and French chalk, and covered finally with a well-chalked layer of cotton tape. The completed joint is placed in a mold, preferably

immersed in a bath of molten sulphur, and kept at a temperature of about 300° F. for a half hour or so. When the vulcanization is complete, a wrapping of friction tape is applied.

CONCEALED WORK IN COMPLETED BUILDINGS

113. Preliminary Examination.—Most buildings of the non-fireproof type can be wired after completion by installing the conductors in flexible fabric conduit in the partitions and under the floors. Before beginning such a job the electrician should carefully determine the location of outlets as given by his specifications and then go over the house and study its layout, in order to determine the most convenient places to run the circuits. A single distribution box is usually located in the basement or attic near the entrance of the service wires, and from there the circuit work begins.

114. Fishing.—The wires, encased in the flexible tubing, are installed by the method commonly known as fishing. In order to run a line from basement to attic, for instance, the electrician takes up a single floor board at the side of the attic and lowers a thin steel tape, called a snake. When a clear drop to the basement has been found by exploring with the tape, the end is lowered to the basement, where the helper is ready to attach the wires, already placed in the flexible tubing. The electrician then withdraws the snake, bringing the wires with it. The operation of fishing is shown in Figs. 82 and 83; in the latter, the wires are being fished between wall outlets on adjacent floors.

Sometimes in fishing between floors through partitions cross-pieces between studs are encountered. In such cases the cross-pieces can be bored by an ordinary wood bit fastened in the end of a gas pipe in the other end of which is secured a brace. If the drop for the wires is behind a door casing, it may be possible to remove the casing and fish the wires around the cross-pieces.

Wires for ceiling outlets are fished under the floors. When floor boards can be removed and the wires run parallel to the

joists, this is a simple matter, requiring only the removal of a board near the partition and of one over the outlet, as shown

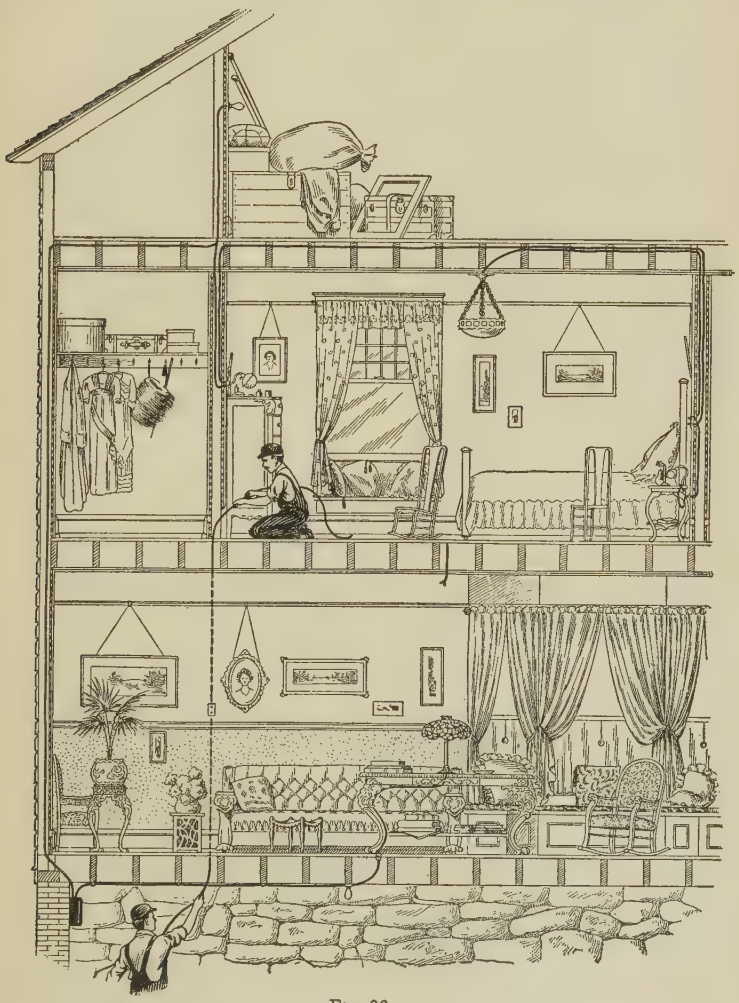


FIG. 82

in Fig. 84. When the floor boards of a room cannot be disturbed, it may be possible to run the snake from a closet, from which the removal of a board is usually permissible, directly

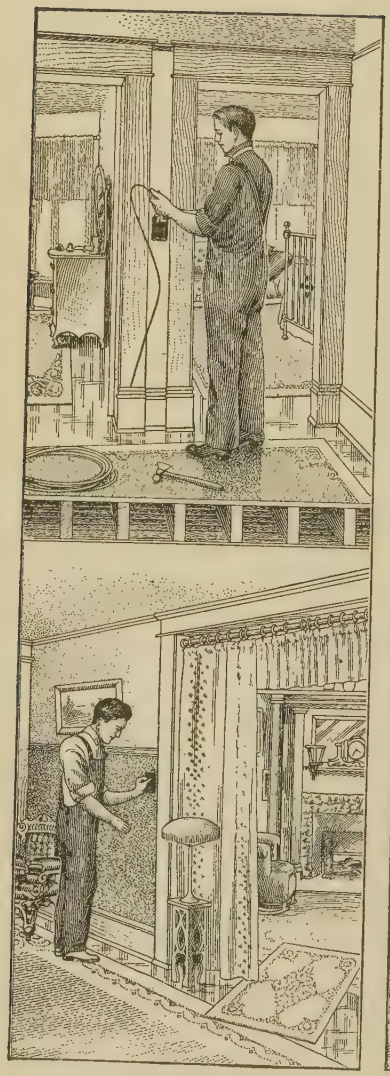


FIG. 83

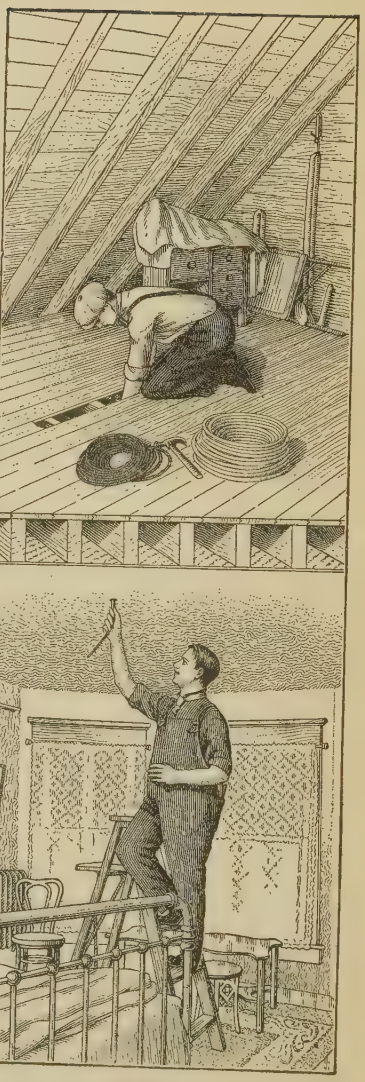


FIG. 84

to the opening in the ceiling; but where the joists run crosswise to the direction in which the wires are to be fished, a portion of the baseboard must be removed and the wires carried by this route to a point on the floor where they can be run parallel to the beams.

Armored cable, which, though more expensive than wires in flexible tubing, is superior in all other respects for this work, is fished from point to point in the manner just described.

115. Fastening Ceiling Fixtures.—When the floor above a ceiling outlet cannot be removed no opportunity is offered for nailing between the joists any support for the fixture stud. If the fixture is a light one, the fixture stud can be screwed directly to the lath, using a stud with as large as possible a spread between the feet. It is good practice, even with a light fixture, to reinforce the lath at the opening by a wooden block about half inch thick and small enough in diameter to go inside the fixture canopy. The weight of a heavier fixture can be distributed over a number of lath by slipping through the hole in the ceiling an iron strap tapped in the middle for a gas nipple. The strap can be pushed in endwise and pulled back across the hole by a string previously tied to it at the middle. When the nipple has been screwed into place a block of wood small enough to go inside the canopy is slipped over it and secured by a locknut, thus clamping the strap in position. The fixture can be fastened directly to the nipple. Care should be taken that the strap lies across the lath and not parallel to it.

INSTALLATION OF CONCEALED-CONDUIT WORK

116. System of Procedure.—Before starting to install a new conduit system in a building, the foreman electrician measures the available spaces of the riser shafts for the vertical sections of feeders and mains. He then ascertains the overall space conditions available for placing panel-boards and has the boards laid out by the manufacturer, so that the exact size of the outside panel cabinet may be determined. The foreman also counts up from the plans the number and various sizes of

conduit dropping from the bottom of each cabinet to the floor or rising from the top of the cabinet to the ceiling or floor above, and furnishes the cabinet manufacturer with a templet showing the number and various sizes of holes required in each part of each cabinet. Previous to the receipt of the cabinets, or possibly after they are received, the electrician makes the measurements for the location of the various outlets to which conduit connections are to be made. The measurements are, of course, based on information obtained from the architect or owner of the building. After the rough cabinets have been received at the building, and after the definite location of each has been determined, each is set in place and the various runs of conduit from cabinets to outlets are made. In case it is too early to proceed with the branch circuit work on the floors, the condition of the building may be such that the system of vertical feeder and main conduits can be installed. When the conduit system is complete, the wires can be drawn in and the panel-boards and fixtures mounted and connected up.

Fig. 85

117. Installing Conduit.—Before any conduit is installed, each piece should be examined thoroughly to be sure that there are no obstructions or rough places. An obstruction may prevent the drawing through of the wires or cables; and, even if the wires can be drawn through, the insulation may be so badly damaged by rough spots in the conduit that a break-down will soon occur. Equal care should be taken to remove all burrs or sharp edges from the ends of conduits, especially after a piece has been cut and before it has been threaded. The removal of burrs from the inside edge of a piece of conduit is quickly accomplished by the use of a reamer, Fig. 85, held in an ordinary brace. Before a piece of conduit is threaded the end should be smoothed off with a file. Before two pieces of conduit are coupled together, the threads should be painted with white lead to make the joint water-tight. The paint also protects the iron from corrosion.

Bends in rigid conduit should not be too short and care should be taken that the conduit is not flattened out at the bend. The correct types of bending tools or machines, three kinds of which are shown in Fig. 86, should be employed in making bends. Conduits should never be bent over a sharp edge.

Conduit ends should never be left open for any length of time where they are likely to become stopped with refuse or where water may enter them. The ends should always be kept closed by wooden plugs, or gas caps until the wires are to be installed.

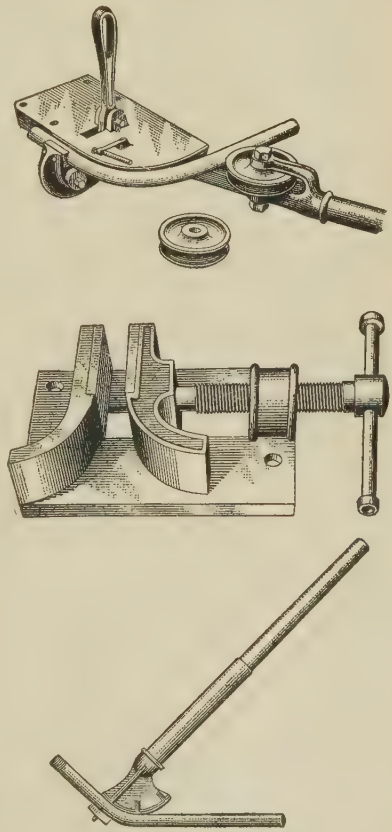


FIG. 86

118. The average conduit job will require the following tools, in addition to those already mentioned: Bench vises to hold the conduits while they are being cut and threaded; hack saws and pipe cutters for cutting conduits and nipples; stock and dies for threading; and an assortment of pipe wrenches. Special hand- and motor-driven machines are used for cutting and threading conduit on large installations where a large amount of such work is to be done.

119. Installing Wires in Conduit.—Wires should never be pulled into concealed conduit until the system is complete, floors laid, and walls and ceilings plastered. To facilitate the insertion of the wires, it is good practice to blow powdered soapstone into a conduit, especially if the run is very long and has many

bends or offsets. A steel snake is used as a pathfinder for the wires. In the case of most branch circuit work the wires are drawn into the conduit by attaching them directly to the tape; but where a strong pull is required to draw in a wire or cable of considerable size, a hemp rope or a steel cable is drawn into the conduit by the tape, and the wires are drawn in by means of the rope. Large lead-encased cables, such as generator leads, require the use of a block and tackle, a strong enough pull being impossible by hand. Wires are drawn into conduits from reels mounted on improvised axles of conduit, crowbars, or anything else that will allow the reels to rotate easily as the wires pass through the conduits.

Few tools other than screwdrivers and wire pliers are required for the installation of wires in conduits. Hack saws are used to cut wires and cables too large to be cut by pliers or bolt cutters. Soldering torches, blow torches, and soldering irons are necessary for jointing and for sweating wire or cable ends into terminal lugs at switchboards, panels, etc.

TESTS

120. Kinds of Tests.—Tests on completed wiring are made to discover grounds, crosses, and wrong connections. Two tests are usually made: one before installing the fixtures and one after. Often fixtures are tested independently before they are put in place. All such tests are essentially tests of insulation resistance.

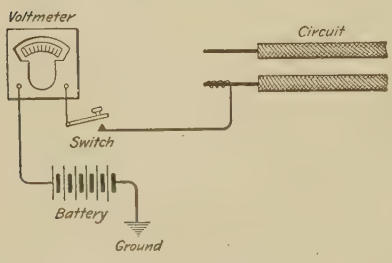


FIG. 87

121. Voltmeter Method. The voltmeter test is the most reliable of the various methods of testing the insulation resistance of electric wiring. A voltmeter capable of indicating from zero to 150 volts and a source of electromotive force—a battery of dry cells will serve—are required. The resistance of the voltmeter must be

known, but the resistance of the battery, if a battery is used, can be neglected.

The voltage E of the battery is first measured by connecting the voltmeter directly across the battery terminals. The voltmeter is then connected in series with the insulation resistance as in Figs. 87 and 88, and the reading E_1 noted. If R_1 is the resistance of the voltmeter, the insulation resistance is

$$R = \frac{R_1 \ (E - E_1)}{E_1}$$

EXAMPLE.—The insulation resistance between the conductors of a circuit was measured by means of a voltmeter having a resistance of 20,000 ohms and a battery with an open-circuit electromotive force, as measured by the voltmeter, of 40 volts. With the insulation resistance in series with the voltmeter, as in Fig. 88, the reading was 5 volts. What was the insulation resistance?

SOLUTION.—The values to be substituted in the formula are $R_1 = 20{,}000$, $E = 40$, $E_1 = 5$. The insulation resistance was

$$R = \frac{20{,}000 \times (40 - 5)}{5} = \frac{20{,}000 \times 35}{5} = 140{,}000 \text{ ohms.} \quad \text{Ans.}$$

122. Magneto Method.—A **magneto** is a small, hand-operated, alternating-current generator with permanent field magnets. For testing purposes, magnetos are mounted in a portable case, or box, with a bell. When making a test, the terminals of the instrument are connected to the circuit to be tested; if the bell can be rung, the circuit is faulty.

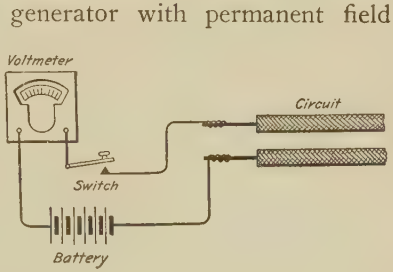


FIG. 88

Magnetos are designed to ring the bell through resistances of 5,000 to 10,000 ohms, or more. A magneto set cannot be used to measure insulation resistance; it is useful only in indicating the existence of a fault. As a rule, magnetos are not to be recommended for testing; because, if a circuit under test has sufficient capacity, a ring will be obtained, even though the insulation is without fault. Cable circuits are especially likely to possess capacity, and magneto tests on them are therefore

unreliable. The magneto is, however, useful for testing branch circuits and fixtures.

123. Miscellaneous Methods.—The Wheatstone bridge, ohmmeter, and the megger can also be used for measuring insulation resistances. The first has the disadvantages of requiring a man experienced in its use and of requiring, in some cases, too long a time for a test. The ohmmeter is easily manipulated, and is direct-reading, but its range is too small for most insulation tests. The megger has none of these disadvantages and requires no external source of electromotive force, being superior in the last respect to the voltmeter.

124. Method of Procedure in Testing.—In testing an interior wiring installation with the fixtures in place, the method of procedure is to remove all lamps and disconnect all other apparatus, but to close all switches and have the circuits otherwise properly connected and fuses inserted. A bunch test of all feeders, mains, and branch circuits is then made at the bus-bars of the main switchboard. A test should first be made between each pair of the conductors themselves, after which a ground test should be made between each conductor and the ground. If leakage or a short circuit is indicated by the test at the bus-bars, the fault must be located by a process of elimination. To accomplish this, the feeders are cut out of circuit one at a time by opening the feeder switches or removing the fuses. When, upon opening a certain circuit, the indication of trouble disappears, the fault is known to be somewhere on that circuit. By following this feeder and its mains to the various centers of distribution the panel-board to which the defective branch is connected can be found, and the trouble on the branch can be located by inspection. Most short circuits and grounds will be found at the outlets, where the wiring connects with the fixtures; but, sometimes metallic veins in slate panel-boards cause leakage between the bus-bars; such panel-boards must be replaced.

The insulation resistance of an installation should be inversely proportional to the amount of wiring. The Code rules specify the value of insulation resistance that must be maintained.

LOCATION AND CALCULATION OF FEEDERS AND MAINS

LOCATION OF FEEDERS AND MAINS

125. Influences Determining Location of Feeders and Mains.—The location of feeders and mains in wiring installations is one of the first matters to be determined; their exact location must be fixed with reference to the design of the building and the location of water pipes, steam pipes, ventilating ducts, elevator shafts, etc. It is preferable, if possible, to obtain continuous vertical rising shafts for the feeders and mains so as to avoid horizontal runs under the floors, which must be made thicker than otherwise necessary if large conduits are to be accommodated. A center of distribution (panel) should be located at each rising point, because at these points the branch circuits originate. In a building of considerable floor area, where several rising points and several centers of distribution on each floor are necessary, the panels should be so located that the branch circuits do not exceed 100 feet in length, if possible.

126. Number of Feeders.—The number of feeders will be determined largely by the size of the building and, to a certain extent, by the desirable control of the lamps. For example, in many cases, particularly in office buildings, it is desirable to have separate feeders for the lamps in the halls, thereby making it possible to control hall lamps from the main switchboard. Separate feeders should be run for motors also, because motors, especially if started and stopped frequently or if operated on variable loads, interfere with the voltage regulation on the lighting feeders to such an extent that the lights fluctuate to a marked degree. Heating circuits that handle any considerable load should also be supplied by separate feeders.

Special feeders for exterior or decorative lighting should also be separate and controlled by switches installed on the main switchboard for the building.

The number of feeders depends also on the loads to be carried, because there is a limit to the size of conductor that it is economical or convenient to use. In general, it is not advisable to use conductors of over 1,000,000 circular mils area for feeders or mains, and if a greater area is required to avoid an excessive drop in voltage, the load should be divided among several feeders.

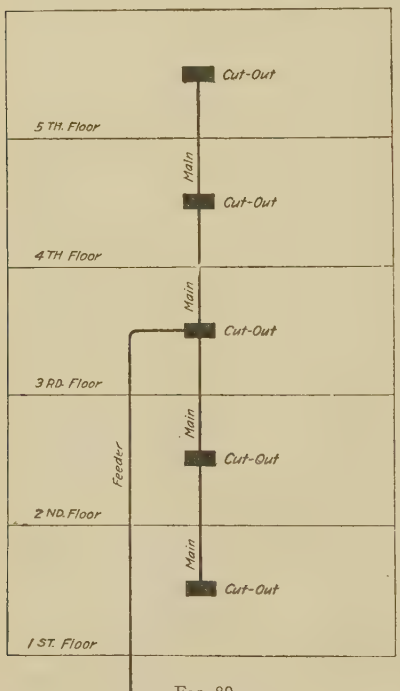


FIG. 89

127. Simple Feeder Layouts.—Though it is sometimes desirable to control the centers of distribution on one floor by a separate switch at the main switchboard, such a system should be avoided, if possible, because a separate feeder for each floor is required and horizontal mains from one panel to another are necessary. The most economical method is to supply several centers of distribution located on the same riser from one feeder as in Figs. 89 or 90. In cheap loft buildings, the method of Fig. 90 is often used to supply as many as seven or eight floors; but this method for so many floors is quite objectionable, as too many circuits depend on a fuse protecting a single feeder and in case of a short circuit the area affected by the disturbance is considerable. Furthermore, the voltage at the top floor must necessarily be considerably less than at the bottom floor.

It is usually advisable to run all of the conductors constituting a given feeder in one conduit. This is absolutely essential if alternating current is to be used, and is usually wise even if direct current is to be used, because a future change to alternating current can thus be anticipated.

In arranging the feeders and mains, it is good practice to make a preliminary layout, taking into consideration the space available for the risers, the number of centers of distribution that it is possible to obtain, and the estimated loads to be supplied by the feeders. A preliminary diagram should then be made showing the centers of distribution, the load in amperes supplied by each center, and the calculated lengths of the feeders and mains. The next step is to determine the sizes of the feeders and mains, assuming allowable losses.

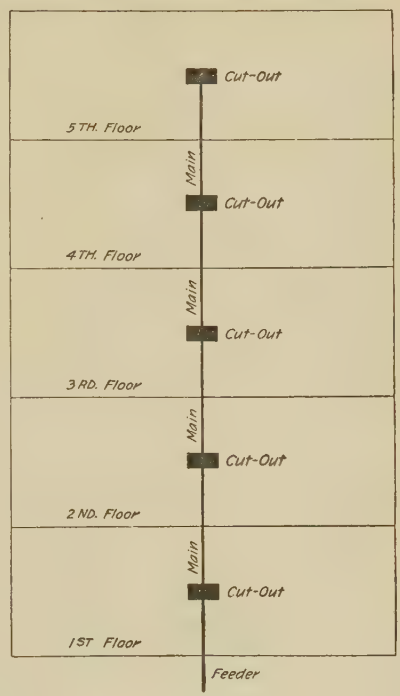


FIG. 90

CALCULATIONS FOR FEEDERS AND MAINS

PRELIMINARY CONSIDERATIONS

128. Factors Governing Calculations for Interior Wiring. The size of a conductor for a given purpose in an interior wiring installation is determined by two factors, the allowable voltage drop in the conductor and the carrying capacity of the wire or cable.

On the basis of commercial economy alone, the proper conductor to use for a given purpose is one in which the cost of energy lost as heat in the conductor in a given time is equal to the interest on the cost of the conductor itself for the same time. Electric considerations are, however, usually those that must be taken into account in determining the maximum voltage drop allowable; the life and brilliancy of incandescent lamps and the speed and output of electric motors all vary with the voltage impressed at the terminals of the apparatus. The allowable voltage drop is then the difference between the voltage at the main switchboard and the voltage required at the terminals of apparatus.

A conductor may be of sufficient size to carry its load without exceeding the allowable voltage drop and yet have current-carrying capacity below that specified by the National Electric Code. Carrying capacity then becomes the factor controlling the size of the conductor. In general, the size of a long conductor will be determined by voltage drop and of a short conductor by the carrying capacity. Except in the case of flexible cord used for wiring fixtures and in the case of low-potential work, no conductor smaller than No. 14 B. & S. is permitted by the code, even though the requirements as to voltage drop and carrying capacity are met by a smaller conductor.

129. Method of Proceeding With Calculations.—Before the size of a conductor for a given voltage drop can be calculated, the load to be carried by the conductor must be known. All of the lamps of a large installation are seldom used simultaneously, and in calculating voltage drop it is usually safe to assume a load less than that required by all of the lamps in the area supplied by a given feeder or main. The percentage of load to be assumed varies with the type of building and with the number of lamps supplied by one feeder; the greater the area supplied, the less likely that the entire load will be in use at one time. The calculations for a branch circuit should be made for the maximum possible load on that circuit, because the small number of lamps supplied may frequently be used simultaneously; but in most instances, all of several hundred

lamps supplied by a feeder will rarely burn at the same time. Though no fixed rule can be given, 80 per cent. of the maximum possible load can usually be safely assumed when calculating the drops in feeders for hotels or office buildings. For the feeders supplying the lower floors of hotels, however, particularly those supplying the restaurant, lobby, ball room, etc., the maximum possible load should be used in calculations. In a factory building also, where all of the lamps may be used simultaneously, the greatest possible load should be used.

When carrying capacity is the basis on which the size of a conductor is to be determined, the maximum possible load must be taken into consideration. It is not safe to assume that no contingency will ever arise to require the simultaneous burning of all lamps on a feeder; when such a contingency does arise, the feeder must be able to carry the load without overheating.

130. Having determined the load to be transmitted by the various conductors, the next step in the calculations is to assume a certain voltage loss to be allowed in the various feeders, mains, and branches comprising a circuit between the main switchboard and the consuming devices. The amount of this loss will vary with the size of the building and with the lengths of the circuits, and should be kept as small as possible without going to the extreme of using unnecessarily large conductors. In ordinary practice, the drop from the point of service supply to lamps will vary from 3 to 4 per cent. It is usual to allow approximately 1 to $1\frac{1}{2}$ per cent. of this drop in the branch circuits and the balance in the feeders and mains. In conductors supplying motors, the total drop can be increased to 5 or 6 per cent., because motors usually do not require as close voltage regulation as lamps.

After the percentage of drop has been determined, the next step is to estimate the lengths of the various feeders and mains. A rough diagram of the feeder system should then be made, showing the feeders and mains from their points of origin to the cut-out panels, indicating on the diagram the loads at the

various panels and the estimated lengths of the conductors. This being done, the numerical work of the calculations can be taken up.

DIRECT-CURRENT CALCULATIONS

131. Two-Wire Circuits.—The voltage drop in a conductor of resistance R ohms carrying a direct current of I amperes is $u = R\,I$. The resistance R of a copper conductor l_1 feet long and a circular mils in cross-sectional area is $\frac{10.8 l_1}{a}$; therefore, if the allowable drop in a pair of feeder or main conductors each l feet long and carrying I amperes is u volts, each of the conductors must have a cross-sectional area of

$$a = \frac{21.6\,l\,I}{u} \text{ circular mils}$$

The values of l and u can be determined as explained in Art. **130.** The value of I is found by adding together the inputs, in watts, required by all apparatus supplied by the given feeder or main, dividing this total by the voltage at the apparatus, and taking the proper percentage of the quotient so obtained. If the amperes input of a motor cannot otherwise be determined, the value can be found by dividing the output, in watts, by the efficiency and the rated voltage. Average efficiencies of direct-current motors are given in Table IV.

TABLE IV

AVERAGE EFFICIENCIES OF 110- AND 220-VOLT DIRECT-CURRENT MOTORS

Size of Motor Horsepower	Efficiency Per Cent.
1 to 5	80
5 to 20	85
25 to 100	90
150 to 200	93

Motor leads must be designed to carry a current at least 25 per cent. greater than that for which the motor is rated.

132. Having found the number of circular mils required, a wire table should be consulted to find the size of wire or cable having a cross-sectional area next greater than or very nearly equal to the calculated value. The National Electric Code table of carrying capacities should then be consulted to ascertain if the size chosen has the specified carrying capacity; if not, a conductor large enough to carry the maximum possible load on the given main or feeder must be selected.

If the size of the conductor, in circular mils a, is known, the voltage drop for a given current I amperes is

$$u = \frac{21.6\, l\, I}{a} \qquad (1)$$

The current that can be carried by a conductor a circular mils in cross-sectional area with a drop of u volts is

$$I = \frac{a\, u}{21.6\, l} \text{ amperes} \qquad (2)$$

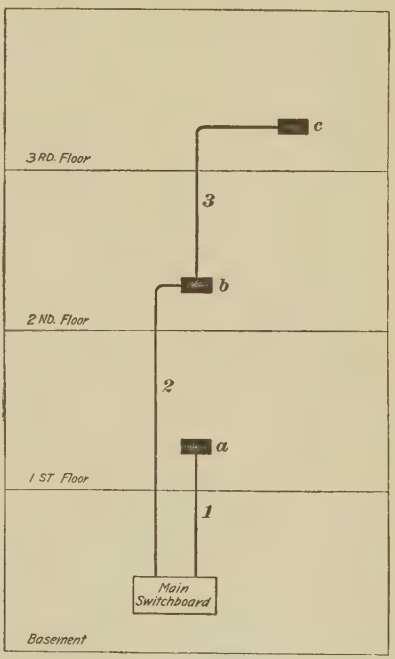


FIG. 91

133. Three-Wire Circuits.—Branches from a three-wire direct-current feeder or main are usually so arranged that the load on the feeder or main is nearly balanced and calculations are carried out on this basis. The formulas of Arts. **131** and **132** are applied by treating the balanced three-wire system as a two-wire system with a voltage equal to that between the outside wires of the three-wire system. The size of wire for the neutral should be equal to that determined by the calculations for the outside wires.

EXAMPLE 1.—In Fig. 91, cut-out panels *a*, *b*, and *c* are supplied by feeders *1* and *2* and main *3* of a direct-current, two-wire system. The conditions of the installation are arranged as follows:

	LENGTH FEET	LOAD AMPERES	ALLOWABLE DROP VOLTS
Feeders *1*	50	60	2.0
Feeders *2*	110	50	2.0
Main *3*	30	20	.5

The 50-ampere load on feeder *2* includes the load of 20 amperes on main *3*. Find the sizes of rubber-covered conductors to be used for each feeder and the main.

SOLUTION.—Applying the formula in Art. **131**, the cross-sectional area of feeder *1*, to give the required drop, should be $a = \frac{21.6 \times 50 \times 60}{2} = 32{,}400$ cir. mils. On a basis of voltage drop, No. 5 B. & S. wire would be chosen, but, by Table II, *Electric Wiring*, Part 1, the carrying capacity of No. 5 wire is only 55 amp. and No. 4 or larger should be used for feeder *1*, to comply with the National Electric Code rules. Ans.

To give a drop of 2 volts, feeder *2* should have a cross-sectional area of $a = \frac{21.6 \times 110 \times 50}{2} = 59{,}400$ cir. mils. No. 2 B. & S. wire, with a cross-sectional area of 66,370 cir. mils. and a carrying capacity of 90 amp. should be used. Ans.

For a drop of .5 volts under the given conditions, main *3* should have a cross-sectional area of $a = \frac{21.6 \times 30 \times 20}{.5} = 25{,}920$ cir. mils. The next larger conductor is No. 6 B. & S., with a cross-sectional area of 26,250 cir. mils and a carrying capacity of 50 amp.; this should be used. Ans.

EXAMPLE 2.—Fifty, 60-watt, 110-volt, incandescent lamps are connected to a panel board located 80 feet from the main switchboard; 80 per cent. of the lamps will probably be in use at one time. The panel is supplied by a two-wire, direct-current feeder direct from the switchboard. A total drop of 3 per cent. between the switchboard and the lamps is allowable, 1 per cent. in the branch circuits and 2 per cent. in the feeder. What size of rubber-covered wire should be used for the feeder?

SOLUTION.—Fifty, 60-watt, 110-volt lamps require $\frac{50 \times 60}{110} = 27.3$ amp., 80 per cent. of which is $.8 \times 27.3 = 21.8$, say 22, amp. The allowable drop in the feeder is 2 per cent. of 110, or $.02 \times 110 = 2.2$ volts. Applying the formula in Art. **131**, the feeder-wire must have a cross-sectional area of $a = \frac{21.6 \times 80 \times 22}{2.2} = 17{,}280$ cir. mils. No. 8 B. & S. gauge wire, with a

carrying capacity of 35 amp., can safely be used, though its cross-sectional area, 16,510 cir. mils, is slightly smaller than the computed value. Ans.

If any allowance is to be made for a future increase in load, larger wire should be selected.

EXAMPLE 3.—Other conditions remaining the same as in example 2, what size of feed-wires would be required if the lamps were connected on the 110—220-volt, three-wire system?

SOLUTION.—In this case the lamps would require only $\frac{50\times60}{220}=13.6$ amps. maximum current, 80 per cent. of which is 10.9, say 11 amp. The allowable drop is 2 per cent. of 220, or 4.4 volts. Then, $a=\frac{21.6\times80\times11}{4.4}=4{,}320$ cir. mils will be the proper cross-sectional area, and No. 14 wire (4,107 cir. mils), with a carrying capacity of 15 amps., may be used, though No. 12 wire would be preferable. Ans.

EXAMPLE 4.—If No. 6 B. & S. wire is used for the feeder in example 2, what will be the actual drop in the feeder-conductors?

SOLUTION.—Substituting in formula **1**, Art. **132**, the drop will be

$$u=\frac{21.6\times80\times22}{26{,}250}=1.4 \text{ volts.} \quad \text{Ans.}$$

EXAMPLE 5.—How many 40-watt, 110-volt lamps can be connected to a panel board supplied by direct-current through a 75-foot feeder of No. 2 B. & S. rubber-covered wire if the allowable drop in the feeder is 1.5 volts?

SOLUTION.—According to wire tables, the cross-sectional area of No. 2 wire is 66,370 cir. mils. Applying formula **2**, Art. **132**, the current that can be carried by the feeder with a drop of $u=1.5$ volts is $I=\frac{66{,}370\times1.5}{21.6\times75}=61.5$ amp., which is 28.5 amp. less than the allowable carrying capacity of No. 2 rubber-covered wire. Each lamp requires $\frac{40}{110}=.36$ amp.; therefore, 61.5 amp. will supply $\frac{61.5}{.36}=170$ lamps. Ans.

If carrying capacity alone were considered, $\frac{90}{.36}=250$, 40-watt, 110-volt lamps could be connected to the panel.

EXAMPLE 6.—A 25-horsepower, 220-volt, direct-current motor is to be supplied with electric energy through a 60-foot, two-wire feeder in which the permissible voltage drop is 5 per cent. What size slow-burning, weather-proof conductors should be used for the feeder?

SOLUTION.—By Table IV, the efficiency of the motor can be taken as 90 per cent., or .9. The watts input to the motor at normal load is $\frac{25\times746}{.9}$;

allowing 25 per cent. for overload (see Art. **131**), the maximum current input may be $\frac{25\times746\times1.25}{.9\times220}=117.7$, say 118 amp. By the formula in Art. **131**, the cross-sectional area of the feeder-conductors should be $a=\frac{21.6\times60\times118}{.05\times220}=13{,}902$ cir. mils. The use of No. 8 wire, 16,510 cir. mils, would keep the voltage drop well within the limit; but to comply with the National Electric Code specifications, a No. 2 wire, with a carrying capacity of 125 amp., must be used. Ans.

ALTERNATING-CURRENT CALCULATIONS

134. In calculating the sizes of conductors for alternating current, allowance must be made for the power factor of the load. In most interior-wiring installations, the reactance, skin effect, and mutual induction in the wiring are negligible because of the arrangement and dimensions of the conductors. The formulas for alternating-current calculations can be conveniently written as follows:

$$a=\frac{K\,l\,I}{u} \qquad (1)$$

$$u=\frac{K\,l\,I}{a} \qquad (2)$$

$$I=\frac{a\,u}{K\,l} \qquad (3)$$

TABLE V

VALUES OF CONSTANT K IN ALTERNATING-CURRENT FORMULAS

System	Power Factors				
	1.00	.95	.90	.85	.80
	Values of K				
Single-phase	21.6	24.0	27.0	30	34.0
Two-phase, four-wire	21.6	24.0	27.0	30	34.0
Three-phase, three-wire	18.7	20.8	23.4	26	29.4

for which the value of K is selected from Table V. The quantity I is the current per wire. The remaining symbols have the same significance as in the direct-current formulas of Arts. **131** and **132.**

The value of the current per wire for single-phase systems is $I = \frac{p}{n\,E}$; for two-phase four-wire systems, $I = \frac{p}{2\,n\,E}$; and for three-phase three-wire systems, $I = \frac{p}{1.73\,n\,E}$, in all of which p is the load in watts, n the power factor of the load, and E

TABLE VI

APPROXIMATE AMPERES PER TERMINAL FOR ALTERNATING-CURRENT INDUCTION MOTORS

Horsepower of Motor	110-Volt		220-Volt		440-Volt	
	2-Phase	3-Phase	2-Phase	3-Phase	2-Phase	3-Phase
.5	3.3	3.7	1.7	1.8	.9	1.0
1.0	6.0	6.5	3.0	3.2	1.5	1.6
2.0	10.5	12.0	5.0	6.0	2.6	3.0
3.0	15.0	17.0	7.5	9.0	3.8	4.5
5.0	27.0	30.0	13.0	15.0	6.5	7.5
7.5			20.0	22.0	10.0	11.0
10.0			25.0	29.0	12.5	14.0
15.0			35.0	41.0	18.0	20.0
20.0			48.0	55.0	24.0	27.0
25.0			54.0	62.0	27.0	31.0
30.0			70.0	81.0	35.0	40.0
40.0			95.0	109.0	47.0	54.0
50.0			110.0	127.0	55.0	64.0
75.0			165.0	192.0	83.0	96.0
100.0			215.0	248.0	108.0	124.0
150.0			320.0	366.0	160.0	183.0
200.0			410.0	475.0	205.0	237.0
250.0			510.0	590.0	250.0	290.0
300.0			600.0	700.0	300.0	350.0

the voltage at the load. In each case the load on a polyphase system is assumed to be balanced. When the power factor n cannot be accurately determined, average values of 1 for incandescent lamps only, .85 for a mixed load of lamps and motors, and .80 for motors only can be taken in ordinary practice.

135. The full-load ampere rating per terminal of an alternating-current motor is usually given on the name plate; if not, the value can be obtained from Table VI or by the formulas

$$I = \frac{746 \text{ H. P.}}{e\, n\, E} \text{ for single-phase machines,}$$

$$I = \frac{746 \text{ H. P.}}{2\, e\, n\, E} \text{ for two-phase machines, and}$$

$$I = \frac{746 \text{ H. P.}}{1.73\, e\, n\, E} \text{ for three-phase machines,}$$

in all of which expressions H. P. represents output in horsepower, e the efficiency, and the other letters the same as in preceding articles. Average values of efficiency are given in Table VII. To adapt Table VI to single-phase motors

TABLE VII

AVERAGE EFFICIENCIES OF POLYPHASE INDUCTION MOTORS

Horsepower	Efficiency Per Cent.
1	80
5	85
20	88
300	93

multiply the current values for two-phase motors by 2. The values obtained by the use of Table VI or the formulas are normal full-load currents, and at least 25 per cent. additional current should be allowed for starting and overload; under some conditions, an allowance of as much as 50 per cent. must be made.

136. The current used in determining the size of leads for varying speed alternating-current motors depends on the class of service and is specified for each class in the National Electric Code. The term *varying speed motors* here means motors in which the speed varies automatically with the load, decreasing when the load increases, and vice versa. It does not mean motors in which the speed is varied by the use of different windings or groupings of windings, or motors in which the speed is varied by external means, and in which the speed remains practically constant after each adjustment.

EXAMPLE 1.—A 20-horsepower, 220-volt, three-phase, induction motor driving a pump is located 40 feet from the main switchboard. Allowing a drop of 3 volts, what size of rubber-covered feed-wire should be used?

SOLUTION.—According to Table VI, a 20-H.-P., 200-volt, three-phase motor takes 55 amp. per terminal at normal load. Assuming 50 per cent. above normal for starting and overload, the value of I, formula **1**, Art. **134**, becomes $55 \times 1.50 = 82.5$ amp. Since the system is three-phase and the power factor of a motor load can be taken as .80, the value of K, from Table V, is 29.4. Substituting, $a = \frac{29.4 \times 40 \times 82.5}{3} = 32{,}340$ cir. mils. A No. 5 B. & S. gauge wire, 33,100 cir. mils, will keep the voltage drop within the limit, but to carry 82.5 amp. a No. 2 wire will be required. Ans.

EXAMPLE 2.—A 220-volt, three-phase, induction motor rated at 62 amperes per terminal is to be installed at a distance of 80 feet from the switchboard. The power factor is approximately .85. What will be the voltage drop in a feeder of No. 2 B. & S. rubber-covered wire at 50 per cent. overload?

SOLUTION.—At 50-per cent. overload, the motor will take $62 \times 1.50 = 93$ amp. per terminal, which is the value for I, formula **2**, Art. **134**. By Table V, the value of K is 26. By a wire table, the value of a is 66,370 cir. mils. The distance l is given in the problem as 80 ft. Substituting,

$$u = \frac{26 \times 80 \times 93}{66{,}370} = 2.9 \text{ volts.} \quad \text{Ans.}$$

EXAMPLE 3.—How many 50-watt, 110-volt, incandescent lamps can be carried by a two-phase, four-wire feeder of No. 0 wire, 90 feet long with a drop of 2 volts, assuming the load to be balanced?

SOLUTION.—Use formula **3**, Art. **134**, to find the permissible current. The cross-sectional area a of No. 0 wire is 105,500 cir. mils. The allowable drop u is 2 volts. The power factor for lamps is 1 and the constant K,

Table V, is 21.6. The length l of the feeder is 90 ft. Substituting, $I = \frac{105{,}500 \times 2}{21.6 \times 90} = 109$ amp., will give a drop of 2 volts. The current limiting factor in this problem is the 2-volt circuit drop; therefore, since each lamp requires $\frac{50}{110}$ amp., each phase of the feeder can carry $\frac{109 \times 110}{50}$ lamps, and both phases together can carry $\frac{2 \times 109 \times 110}{50} = 480$ lamps. Ans.

ESTIMATES

137. Estimates of the costs of proposed wiring jobs are based chiefly on experience; most contractors keep detailed costs analyses of previously executed contracts, and estimates on proposed work are based on this cost data, due allowances, of course, being made for different items, prices, and conditions.

The cost of wiring is made up of the cost of material, labor, sundries, and overhead expenses. The last named consists of items such as office expense, depreciation of tools, interest on capital, rent, etc. that cannot be charged to any one job, but are divided among various contracts, usually in proportion to the labor costs.

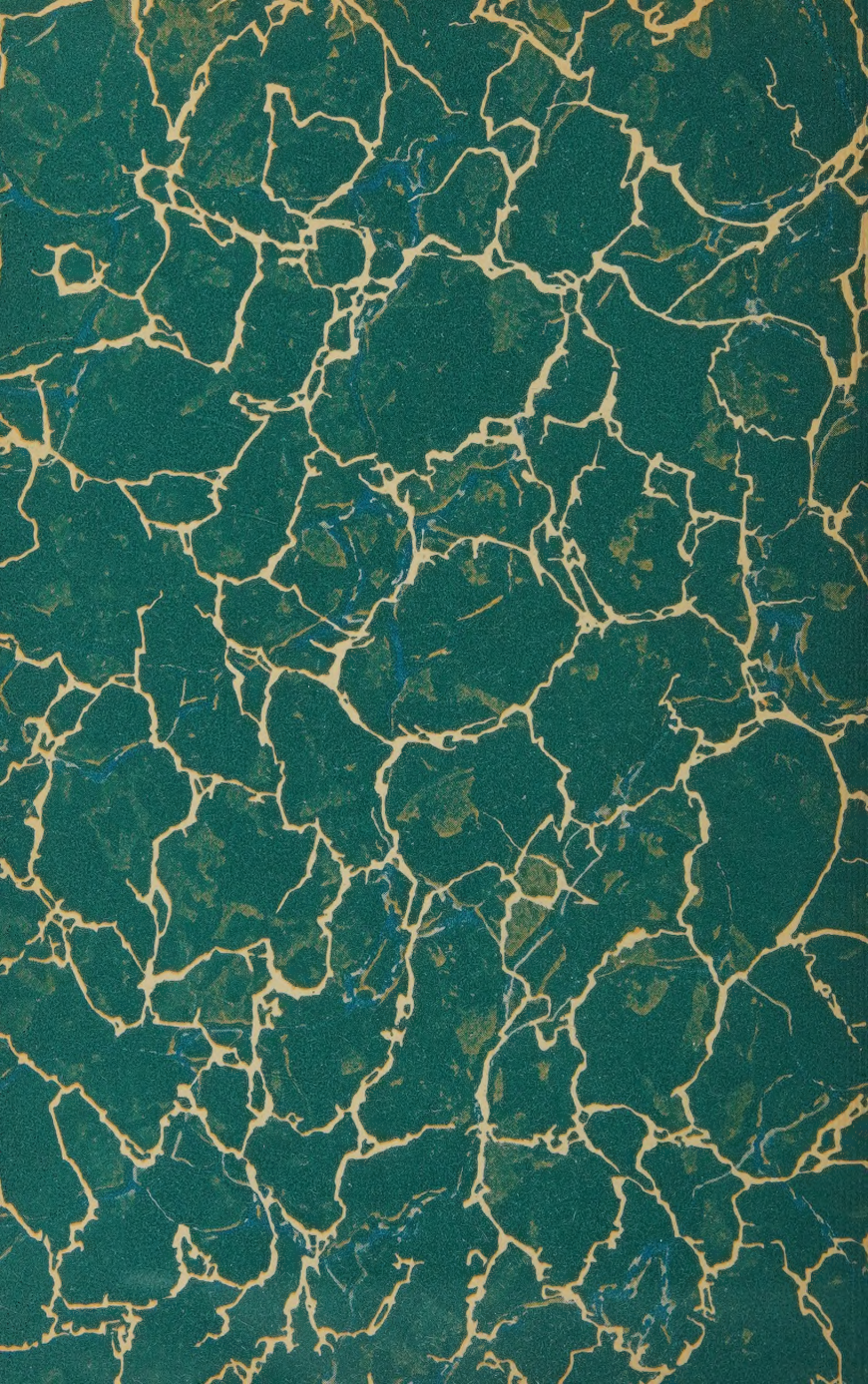
138. The estimator obtains data on a proposed job from the plans and specifications, or, if these lack details, from his own layouts. If the job is a large one, each circuit is analyzed by itself and the quantities of various materials, such as number of outlets, number of switches, number of receptacles, feet of conduit, feet of wire, etc., are recorded, each kind in a separate column, on a *circuit-detail sheet*. When every circuit has been analyzed in this manner, the amounts in the various columns are added together and the total quantity of each item in the contract thus obtained. Items like panel boards and cabinets are handled separately; sometimes special panel boards are required, in which case quotations must be obtained from manufacturers.

An *analysis sheet* is then prepared showing the items, the total quantity of each, the unit costs for labor and material, separately and combined, and the total costs. The prices of

materials are obtained from manufacturers' and jobbers' lists and the prices of labor from the cost data of previous jobs. To the cost of the items that are a part of the installation there must be added the estimated cost of temporary work, such as the erection of scaffolds, and of sundries, such as cartage and carfare; then by adding a percentage to cover contingencies and overhead expenses and a percentage of profit, the amount of the contractor's bid is obtained.

In making estimates, care must be taken to consider the construction of the building, which has great influence on the cost of labor. The estimator should have in mind a tentative plan for carrying out the work on which he is preparing a bid.

139. Sometimes a contractor is asked to bid on a small job without plans, his knowledge of the job being obtained by an inspection of the building. In such cases the bid is usually made on a basis of a certain cost per outlet. Another rough method of estimating is to figure the number of lamps, averaging ten to a circuit, to obtain the number of circuits, then assuming a certain average length per circuit. These methods of estimating are unsafe unless the estimator has had considerable experience in work of certain classes.



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